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Final Technical Report
June 1980

MICROWAVE INTEGRATED CIRCUITS PROCEDURES EVALUATION

Harris Corporation

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MICROWAVE INTEGRATED CIRCUITS PROCEDURES EVALUATION

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RADC-TR-80-201 has been reviewed and is approved for publication.

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Stripline Microwave Circuits	Pre-Seal Visual
Screening Methods	Construction Methods
Lot Conformance	Computer Analysis

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

Microwave Integrated Circuits and Stripline Microwave Circuits are used widely in military ground, airborne, and spaceborne systems. The current military specifications which are invoked generally for hybrid circuits (MIL-STD-883B and MIL-M-38510) require either up-dating to encompass these two classes of microcircuits or new test methods need to be developed.

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New test methods have been developed for the screening, quality, and lot conformance testing of Microwave Integrated Circuits and Stripline Microwave Circuits. Pre-seal visual criteria for Stripline Microwave Circuits was also developed as well as an up-date to Method 2017, MIL-STD-883B for Microwave Integrated Circuits.

Computer analysis of the various construction methods utilized by the industry was performance as a first step evaluation of the construction methods and the proposed criteria.

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ACKNOWLEDGEMENTS

This report is based on the contributions of both individual technologists and the Microwave Integrated Circuit and Stripline Industries.

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Mr. Jerry B. Schappacher

Mr. William J. Vitaliano

John P. Farrell, RADC, recognized the importance of this program to both the military and the industry and provided the leadership to initiate this program.

We would like to personally thank Mrs. Carol Vickers and Ms. Priscilla Leshynski for typing this final report. They deserve our special gratitude for their typing support and patience during the several iterations of the test methods and supporting information.

SUMMARY

Microwave Integrated Circuits (MIC's) and Stripline Microwave Circuits (SMC's) are two classes of microcircuits which remain controversial when viewed in terms of the applicability of MIL-STD-883B and MIL-M-38510.

This program was specifically organized to address the applicability of Methods 2017 and 5008, MIL-STD-883B and Appendix G, MIL-M-38510 to MIC's and SMC's. Data was utilized from industry and the Harris Corporation to evaluate current industry practices. Additional data was compiled on tuning methods, construction methods, visual inspection criteria, and testing methods to develop preseal visual, screening and lot conformance test methods.

Finally, representative models of MIC's and SMC's were developed so that computer analysis of the construction methods could be applied as a first order evaluation. This approach was taken simply as an identification process; that is, to identify potential weaknesses in the construction methods that would degrade circuit reliability.

During the course of the program, consideration was limited to the more complex cases wherein more than one MIC or SMC were packaged within a single package or model (except for an amplifier to cover all configurations).

The proposed test methods and supporting information are a first step toward the goal of amending MIL-STD-883B and MIL-M-38510 to encompass Microwave Integrated Circuits. It is the same goal for Stripline Microwave Circuits. Although it may be argued that a SMC is not a microcircuit, the purpose of this program was not to resolve this dispute, but to initiate the appropriate preseal visual, screening, and lot conformance

test methods.

It is noteworthy that RADC took the initiative to consider nonhermetically sealed passive stripline circuits during the course of this program. They were also open to the active Stripline module (nonhermetically sealed) with the constraint that packaged (hermetic) active devices and passive devices be used.

EVALUATION

The objective of this effort, which supports RADC TPO 4 F-1 Solid State Device Reliability, was to characterize Microwave Integrated Circuits (MIC's) by construction technology and establish criteria to generate test procedures equivalent to Method 5008 of MIL-STD-883 Test Methods and Procedures for Microelectronics and Appendix G of MIL-M-38510 General Specification for Microcircuits. For purposes of this investigation the following definition was used: MIC-A device which provides a high frequency function (e.g. transmitter, receiver, amplifier, oscillator, phase shifter, mixer, signal processor, RF switch, etc.) utilizing stripline, thin or thick films on a dielectric substrate, packaged or chip active and passive components, contained in a hermetic or non-hermetic package.

The program results are considered successful in defining two categories of high frequency devices MIC's and SMC's (Stripline Microwave Circuits) and generating proposed test methods and procedures for these categories using existing hybrid microcircuit test philosophy. Finite element analysis was demonstrated as a useful tool in determining the mechanical and thermal integrity of device packages and their included components.

Procedures to evaluate and control tuning are not included, but will be generated during the evaluation of the test procedures. The present rework limitations cited are being addressed in RADC contract F30602-78-C-0310, "Hybrid Microcircuit Rework Evaluation". The expressed concerns will be considered during the preparation of the final rework procedures for hybrid microcircuits. The recommended burn-in procedure for these circuits will in many cases be a compromise between high ambient temperature and destructively high junction temperatures. For circuits with power devices, it is essential that burn-in be performed under RF conditions. This could also apply to some low power circuits, since it may not be possible to significantly stress critical devices in the circuit under dc conditions.

RADC will prepare and coordinate test methods and procedures for MIC's and SMC's. The Microwave Integrated Circuit test procedures, covering hermetically sealed devices, will be included in MIL-STD 883. The Stripline Microwave Circuit procedures, covering non-hermetically sealed devices, using hermetically sealed discrete active components, will be included in the appropriate military standard(s). Active device chips contained in packages using polymer seals or non-hermetic sealing techniques are not considered acceptable for military applications.

John P Farrell

JOHN P. FARRELL

SECTION 1.0

INTRODUCTION

1.0 INTRODUCTION

MIL-STD-883B, MIL-M-38510, MIL-STD-202, MIL-STD-750 and various military specifications represent a dilemma to the military, system's companies, and manufacturers when invoked on programs which require Microwave Integrated Circuits (MIC) and Stripline Microwave Circuits (SMC). These devices are classified as nonstandard parts which require review and approval of their screening and quality assurance procedures. The manufacturer and the system's company are faced with taking exceptions to the military specifications because they do not directly apply to MIC and SMC which generally results in a lengthy and costly negotiations process.

The screening, lot conformance, and preseal visual criteria as contained in MIL-STD-883B are not entirely applicable to MIC and not defined for SMC.

Faced with a continued dilemma, the manufacturer develops a "vendor equivalent" MIL-STD-883B. It is not to say that the manufacturer's equivalent test methods are wrong; to the contrary, each represents a compromise with respect to cost, quality, and reliability.

The vendor equivalents of several manufacturers were reviewed in conjunction with Harris' experiences at the system and microcircuit levels and applied to the development of test methods which meets the objectives of industry and the military.

Companies which were representative of the MIC and SMC industries were visited to review their approaches and procedures to preseal visual, screening, and lot conformance. Each company contributed additional information on construction methods and very openly discussed their procedures for quality assurance.

Samples of Stripline circuits were purchased, disassembled, and analyzed to view construction methods. To generalize, stripline passive modules are constructed using aluminum housing, RF and dc connectors, and a 'sandwich' construction of organic substrate materials such as G-10, teflon fiberglas, epoxy fiberglas, etc. The modules are not generally hermetic sealed. Literature was researched to augment the physical analysis, and information furnished by the industry further contributed to a model of Stripline circuits.

Harris Corporation's experiences with MIC manufacturers was coupled to our internal experience in MIC design and fabrication to develop several models for MIC's.

At this juncture, models of both MIC's and SMC's existed around which preseal visual criteria could be developed. The purpose was to up-date Method 2017, MIL-STD-883B to encompass MIC's while a separate method would be developed for SMC's.

Method 5008, MIL-STD-883B was reviewed with respect to the applicability of this test method to MIC's and SMC's. Since MIC and SMC modules are not produced in large production quantities (i.e., tens or hundreds of thousands), except in a few circumstances, the respective proposed test methods were developed around smaller lot sizes.

The methods used to tune a circuit to specifications were reviewed to determine the affects on reliability. Tuning methods are identified as part of the critical processes to produce MIC's and SMC's.

Testing requirements for MIC's and SMC's were also reviewed to determine at which places in the assembly, packaging, and, screening sequences testing should be performed. The objective was to establish testing points in the cycle to assure circuit and module reliability without significantly impacting cost. Rework was also considered such that a failed circuit could be replaced prior to sealing or repaired prior to sealing.

Package reseal is of significant cost benefit when one considers the cost of MIC or SMC modules which may contain as many as 15-20 circuit functions. Although reseal is currently prohibited by the military specifications, it remains a point at which a compromise must be reached. The industry cannot be expected to discard modules whose costs often exceed $5,000, and the military must have assurance of reliable and cost effective products. Although not a part of this program, delidding and resealing of MIC and SMC modules must be given immediate attention.

The final challenge of this program was to analyze the construction methods with respect to mechanical and thermal integrity. It was beyond the scope of this program to produce hardware and screen the hardware through the proposed test methods. Computer analysis of the MIC and SMC test models would produce first order data which would identify 'potentially' unreliable construction methods.

The STARDYNE computer program was used to analyze the test models with respect to vibration and mechanical shock.

The ANSYS program was used for thermal analysis of the test models.

The resultant analytical data defined weaknesses in construction methods which would limit the environment for certain types of construction.

Throughout the program, only test models which were hermetically sealed were considered except for the passive Stripline module; that is, a Stripline module which contained no active components or unpassivated passive components.

This program was an excellent beginning. The acceptance of the proposed test methods by the military and industry requires the cooperation of the military and industry.

I wish to emphasize that this program identified areas in MIC and SMC manufacture which require additional study. There is the need to generate reliability data based on the proposed test methods. This can only be accomplished by building hardware and performing the screening and lot conformance testing. Industry can assist by making reliability data available to RADC which supports these technologies and the military can provide the leadership by assuring that systems specifications more clearly define the requirements for MIC's and SMC's.

SECTION 2.0

MICROWAVE INTEGRATED CIRCUIT AND STRIPLINE

MICROWAVE CIRCUIT TECHNOLOGIES

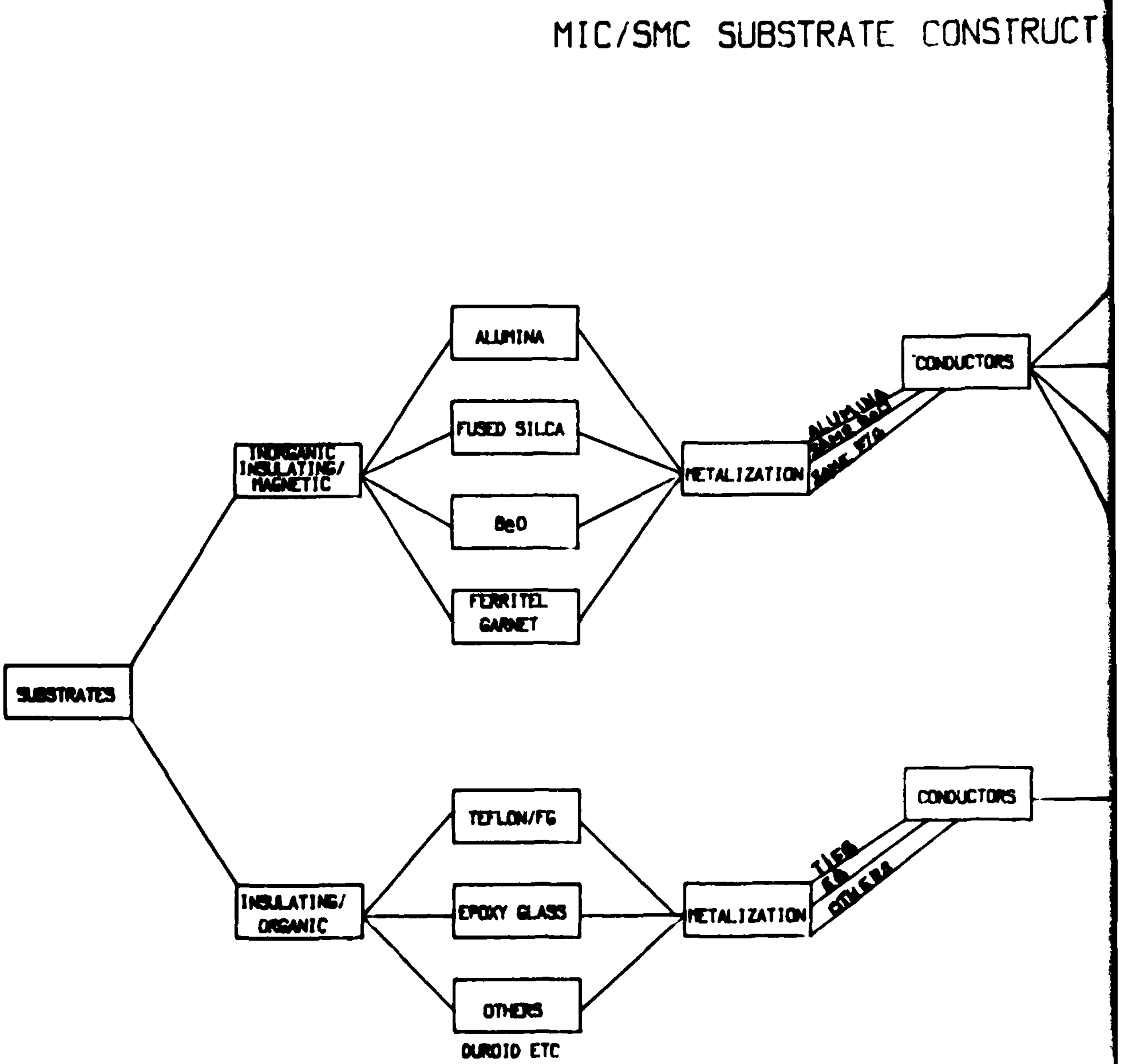
2.0 SUMMARY

To develop visual criteria and test methods it was prudent to limit construction methods to "common practice"; that is, those construction methods which were generally used and accepted by the industry. To establish, as best possible, the common practices in the MIC and SMC industries, literature was researched, manufacturers were visited, and Harris' experiences were combined to establish the basis of "common practice".

It was recognized that each company has developed construction methods and test procedures which meet their respective objectives. Every effort was made to maintain a middle of the road position with respect to the needs of the military and the capabilities and objectives of the industry.

From a review of Figures 2.0-1 through 2.0-5, it is readily observed that MIC's and SMC's are produced using many processes from hybrid micro-circuits (the lower frequency counterparts) and new processes common to MIC and SMC technologies. These figures represent the types of components which are used, the construction methods, the types of packages, the sealing techniques, and the different materials for the substrates. These construction methods represent the module construction methods which are representative of industry practice. Passive Stripline modules were purchased and analyzed to determine construction techniques.

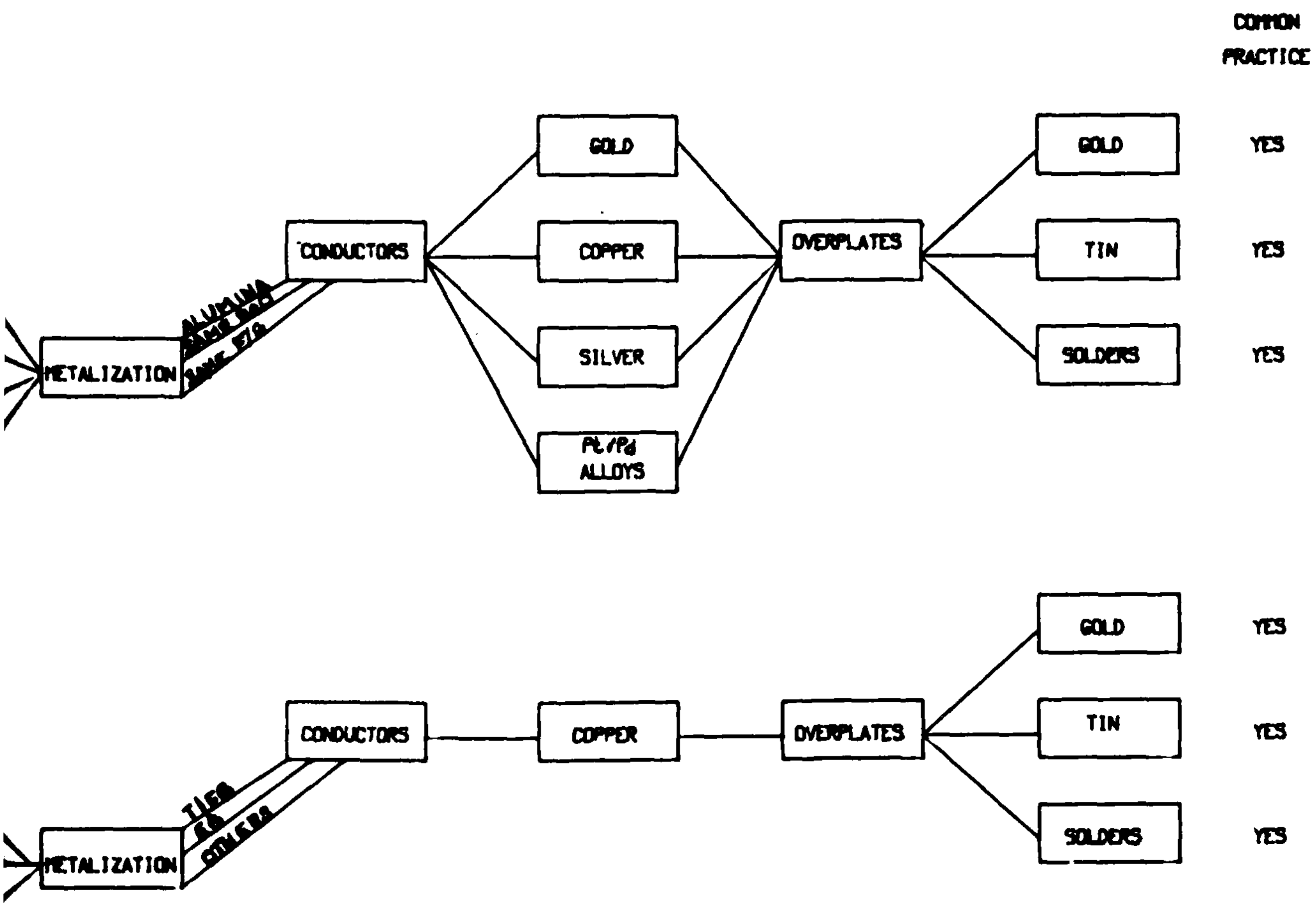
It is recognized that all variations could not be considered but the information that was obtained clearly permits the establishment of the "common practice" concept and encompasses at least 90% of the construction methods.

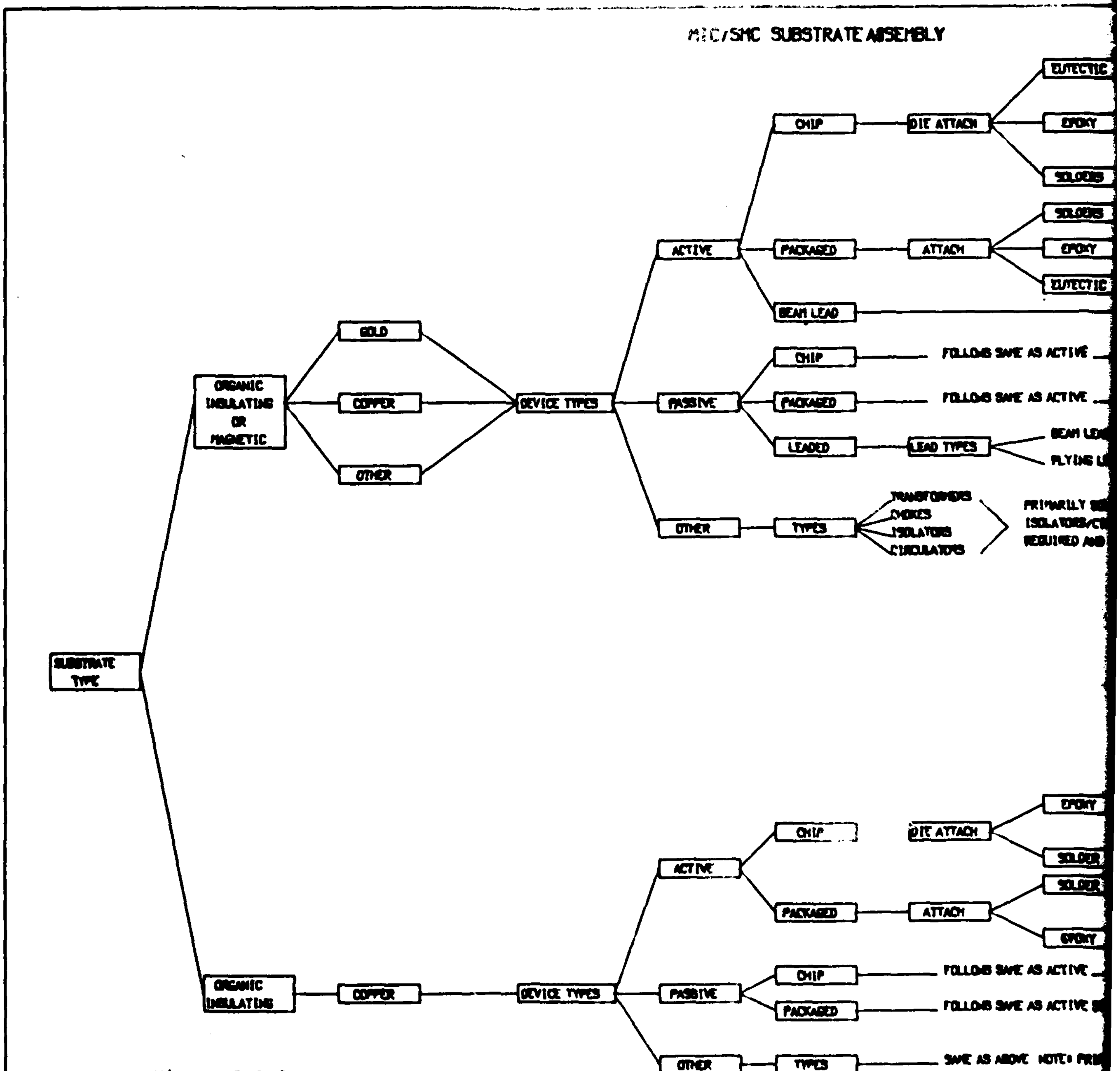


MIC/SMC SUBSTRATE CONSTRUCT
SUBSTRATES
INORGANIC INSULATING/ MAGNETIC
INSULATING/ ORGANIC
ALUMINA
FUSED SILCA
BeO
FERRITEL GARNET
TEFLON/FG
EPOXY GLASS
OTHERS
DUROID ETC
METALIZATION
METALIZATION
ALUMINA
CONDUCTORS
CONDUCTORS

Figure 2.0-1.

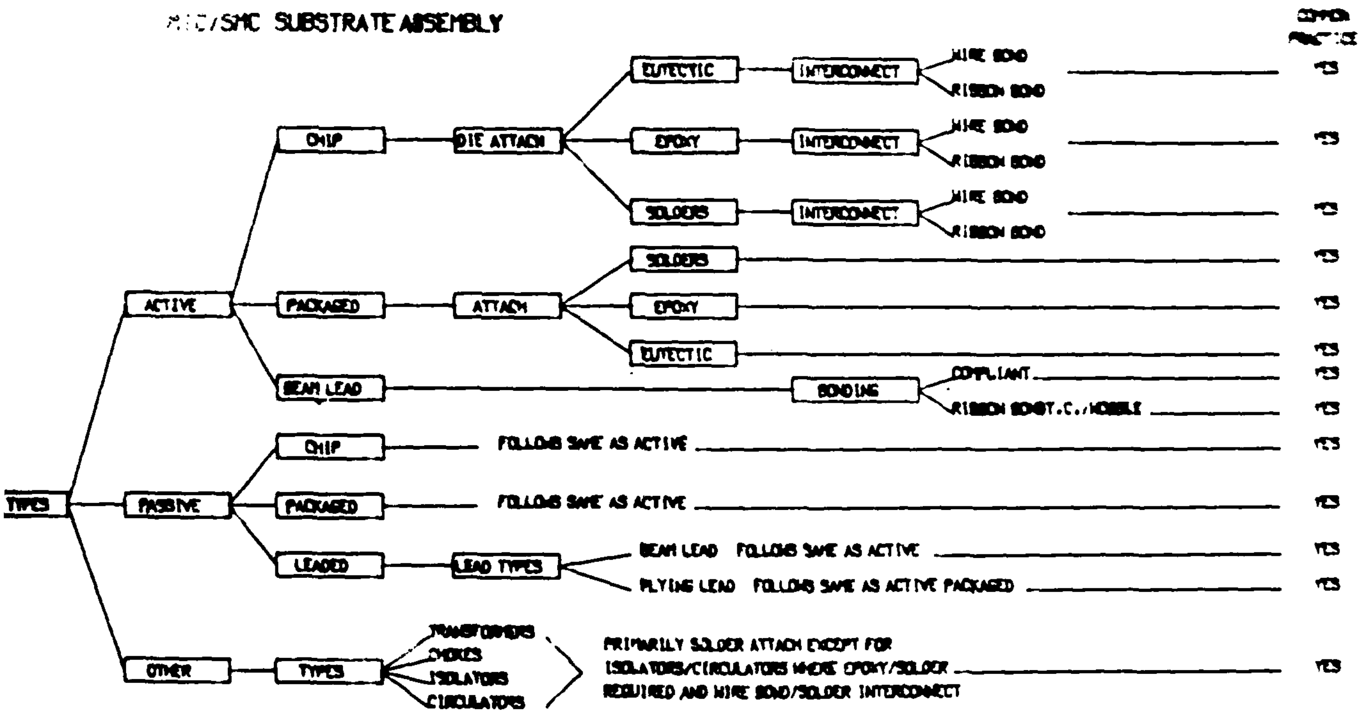
MC SUBSTRATE CONSTRUCTION



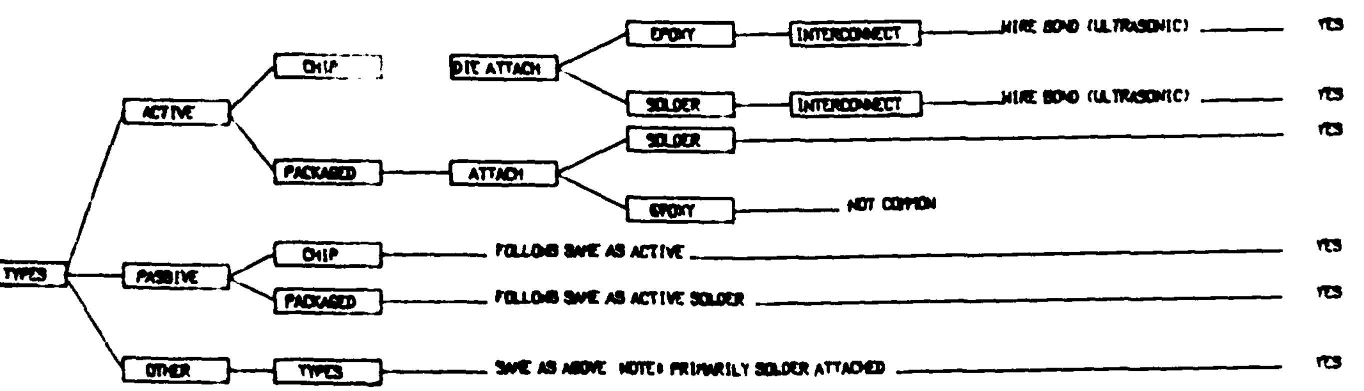


SUBSTRATE ASSEMBLY
SUBSTRATE TYPE
ORGANIC INSULATING OR MAGNETIC
GOLD
COPPER
OTHER
DEVICE TYPES
ACTIVE
PASSIVE
OTHER
CHIP
PACKAGED
BEAM LEAD
DIE ATTACH
ATTACH
EUTECTIC
EPOXY
SOLDERS
FOLLOWS SAME AS ACTIVE
LEADED
LEAD TYPES
TYPES
TRANSFORMERS
CHOKES
ISOLATORS
CIRCULATORS
ORGANIC INSULATING
COPPER
DEVICE TYPES
ACTIVE
CHIP
DIE ATTACH
EPOXY
SOLDER
PACKAGED
ATTACH
PASSIVE
FOLLOWS SAME AS ACTIVE
OTHER
TYPES
SAME AS ABOVE

Figure 2.0-2



MIC/SMC SUBSTRATE ASSEMBLY
COMMON PRACTICE
TYPES
ACTIVE
CHIP
DIE ATTACH
EUTECTIC
EPOXY
SOLDERS
INTERCONNECT
WIRE BOND
RIBBON BOND
PACKAGED
ATTACH
BEAM LEAD
BONDING
COMPLIANT
RIBBON BOND T.C./WOBBLE
PASSIVE
FOLLOWS SAME AS ACTIVE
LEADED
LEAD TYPES
BEAM LEAD FOLLOWS SAME AS ACTIVE
FLYING LEAD FOLLOWS SAME AS ACTIVE PACKAGED
OTHER
TRANSFORMERS
CHOKES
ISOLATORS
CIRCULATORS
PRIMARILY SOLDER ATTACH EXCEPT FOR ISOLATORS/CIRCULATORS WHERE EPOXY/SOLDER REQUIRED AND WIRE BOND/SOLDER INTERCONNECT
YES



TYPES
ACTIVE
CHIP
DIE ATTACH
EPOXY
SOLDER
INTERCONNECT
WIRE BOND (ULTRASONIC)
PACKAGED
ATTACH
NOT COMMON
PASSIVE
FOLLOWS SAME AS ACTIVE
FOLLOWS SAME AS ACTIVE SOLDER
OTHER
SAME AS ABOVE NOTE: PRIMARILY SOLDER ATTACHED
YES

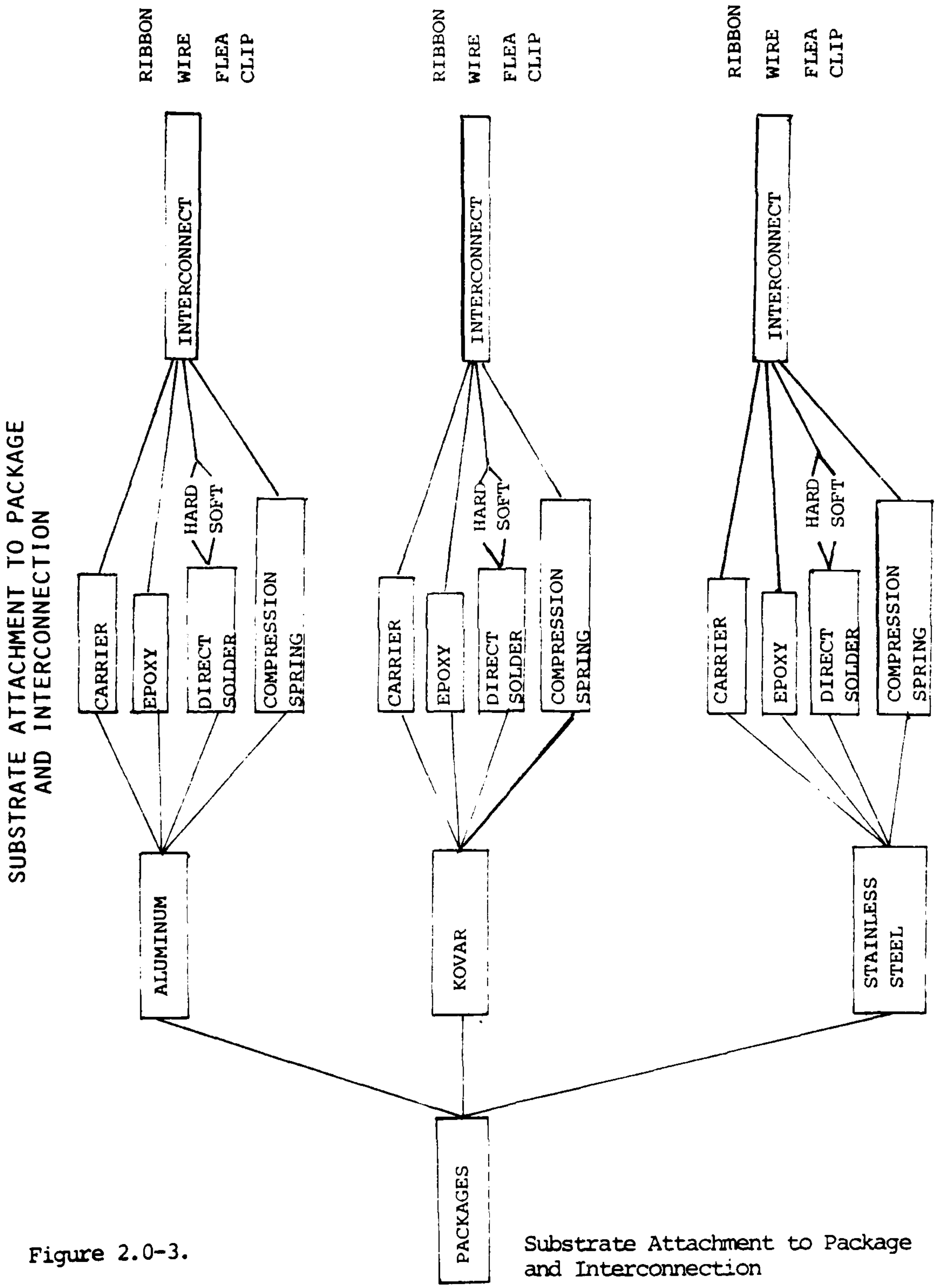


Figure 2.0-3. Substrate Attachment to Package and Interconnection

Figure 2.0-4. Package Construction

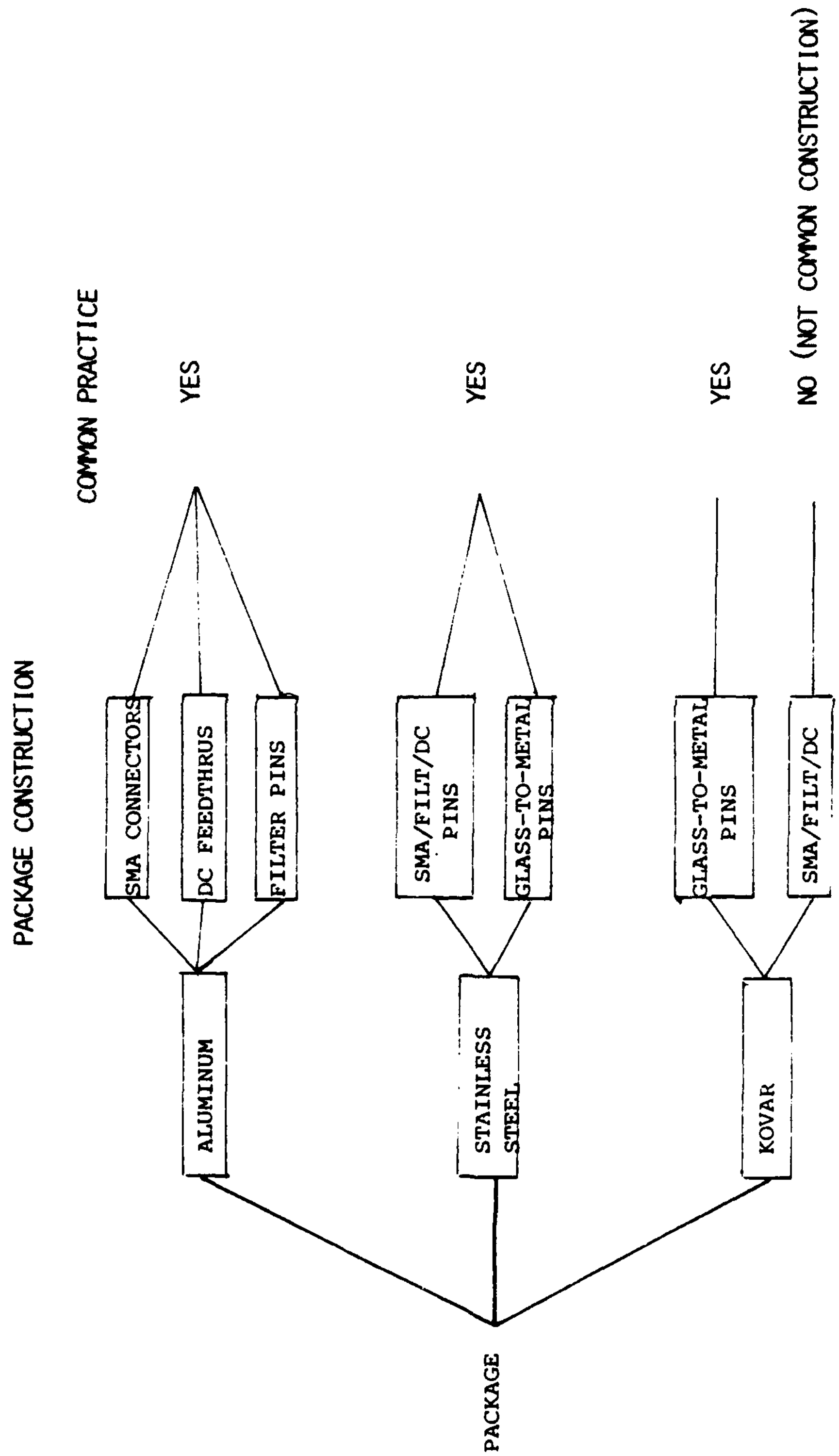
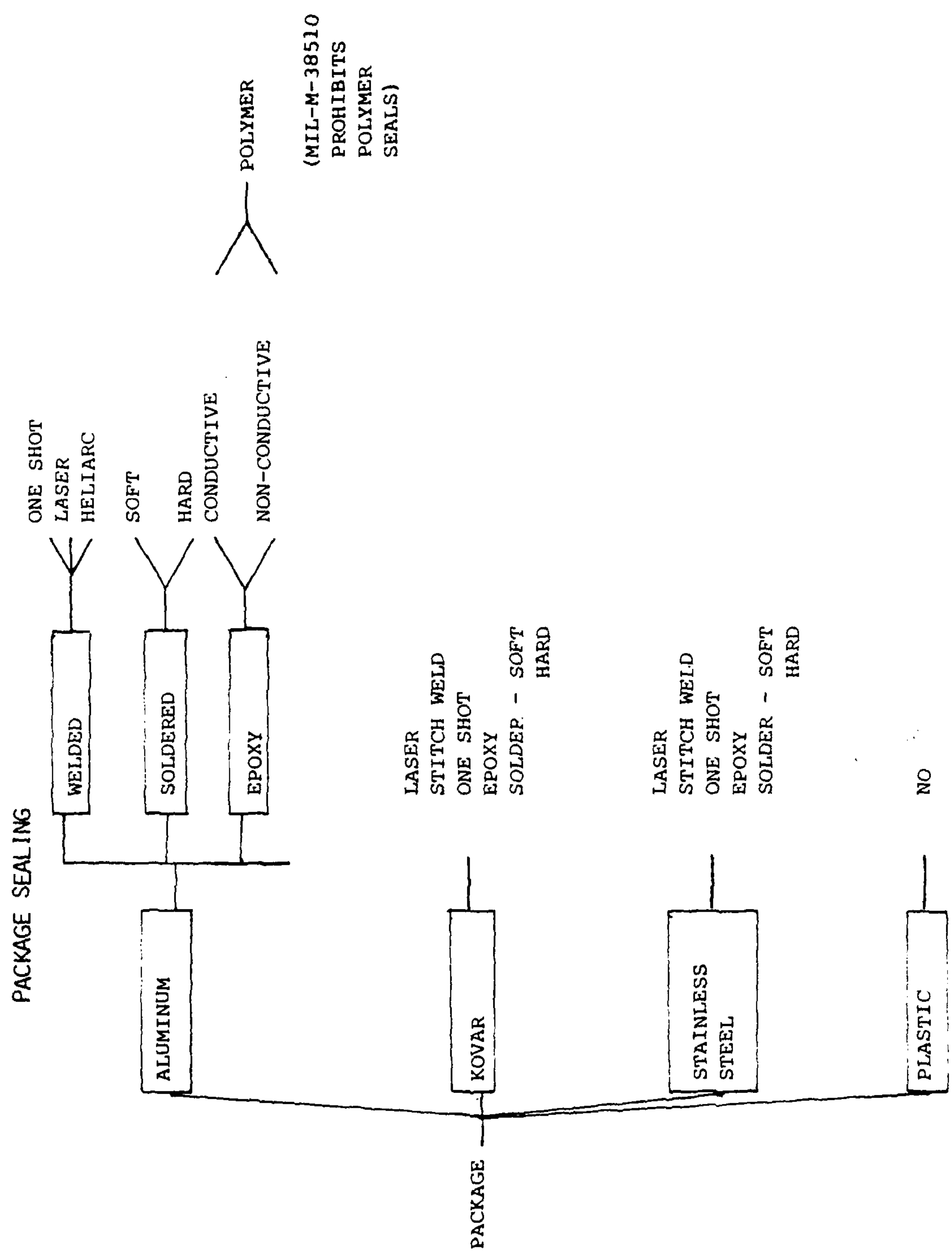


Figure 2.0-5. Package Sealing



The models which represent the common practice are discussed in detail in Section 7.0, Computer Analysis of Construction Methods.

2.1 MIC and Stripline Vendor Data

Technology matrices were developed and forwarded to several MIC and Stripline vendors to obtain a representative cross section of the materials, processes, visual inspection, screening, and lot conformance testing used to produce military modules/products.

The technology matrices are illustrated in Appendix A. It can be readily seen that the matrices cover 95% of the possible combinations of materials, processes, and testing that would be used in module fabrication.

In this section the responses of the vendors will be discussed and the details of the information that each supplied will be presented. The vendor survey was not intended to cover the entire industry; again, its purpose was to obtain sufficient information on the details of construction. The information is 'representative' of the industry.

2.1.1 MIC Vendor Data

The information for MIC technology is contained in Appendix B. This infomation is a summary of the processes and materials which are used by vendors to produce their respective products. It is interesting to note that thin film technology is used primarily to produce MIC's covering the frequency spectrum from 30 MHz to 18 GHz. The substrates used are mainly high purity alumina and fused quartz. The substrate metalization is gold with Nichrome or tantalum nitride resistors.

Chip components are used to avoid the parasitics of packages devices. The chips, particularly active devices, are used so that multiple wire bonds can be placed on the emitter or base of a bipolar device or the source, drain, and gate of an FET device. This multiple wire bonding reduces parasitic inductance and the wire bonds to the device are made using stitch bonds, ribbon bonds, or mesh bonds. This method of bonding has reduced wire pull strength and generally does not meet the requirements of MIL-STD-883B. We recommend that multiple bonding criteria, which is beyond the scope of this study, be added to MIL-STD-883B to encompass stitch bonds, ribbon bonds, and mesh bonds with the appropriate minimum acceptable pull strengths. The same criteria for periodic machine certification as currently contained in MIL-STD-883B should also apply to equipment used to produce stitch and mesh bonds.

The other key area of the technology matrix is tuning methods and this area will be discussed in more detail in Section 5.0.

The MIC vendors who responded did not indicate the use of thick film technology in the processes which were used to produce MIC's; however, at Harris we use thick film technology to produce a variety of 300 MHz products and have conducted studies to use thick films up to 5 GHz. The major restrictions of thick film technology are fine line resolution (i.e., 0.0003" lines and spaces and less) and resolving critical coupler gaps with 0.0001" tolerances. The 'feathering' of the thick film conductor and the characteristics of thick film resistor materials are also limitations. For the sake of this study the Thick Film Matrix was completed to reflect what we at Harris believe to be the restrictions. It is believed that the significant improvements in thick film materials over the past two years will result in MIC's being produced using thick films in larger quantities. The thick film process has the obvious advantage of large quantity substrate fabrication at costs which are lower than thin films. The current limitations can be offset by improved materials and judicious use of thick films for noncritical circuit functions (i.e., phase shifters, amplifiers, except low noise amplifiers, power dividers, etc.).

Packaging and integration of the circuit functions within a single module is primarily accomplished using a machined box. Although more costly to produce, it appears the most cost-effective package when compared to tooling cost amortized over small quantities. The processes and materials used in the module fabrication are contained in Appendix B.

Stainless steel and aluminum are the materials used to produce the modules. I/O is accomplished using SMA connectors and soldered glass to metal seals. With the decreases in tooling cost and increases in production quantities of MIC modules, the kovar module with standard glass to metal sealed I/O's will become more common. Harris will be using a hermetically sealed kovar module to produce J-Band up- and downconverters.

Although epoxy is used widely to achieve non-hermetic seal of MIC modules, the strong position of the military for hermeticity and the availability of hermetically sealable MIC modules will force replacement of epoxy sealing. Again, the impetus for hermetically sealed modules is to assure the reliability of electronic equipment and allow system MTBF specifications to be met.

The reseal criteria contained in MIL-M-38510 must be amended to permit rework of MIC's modules. The cost of the module created by higher levels of integration prohibits the 'throw away' concept.

2.1.2 Stripline Vendor Data

It would be fair to generalize that Stripline Microwave Circuits (SMC) are 'near' cousins to printed wire boards. The departure from this analogy is the extensive use of active and passive chip devices.

The military position with respect to non-hermetically sealed SMC construction methods requires that all active devices be hermetically sealed JANTX equivalent, all microcircuits be hermetically sealed MIL-STD-883B equivalent, and all passive components be passivated.

Comparing MIC construction to SMC construction there are greater variations of construction methods used in SMC than MIC.

The types of boards/substrates that are used vary in electrical, mechanical, and thermal properties. The G-10 material has the highest usage while Teflon and Teflon-Fiberglass are also commonly used.

The boards or substrates are metalized with copper and gold plated; a direct usage of materials and processes from the printed wire board industry.

Both packaged and chip active and passive devices are used in the circuit fabrication. Wire bonding and solder reflow methods are used in the general assembly processes. It is interesting to note that components were mounted directly to the module floor through holes in the boards or near the edges of boards to create a short path to ground.

The package material was most commonly aluminum alloy with SMA connectors and soldered, glassed in pins. Modules are often constructed and literally bolted together to form the housing. Many housings were found to be complex geometries to provide RFI shielding between circuit functions.

The modules were not generally hermetically sealed but processes have been developed to seal aluminum modules. These processes use heliarc welding or laser welding.

The construction of the passive stripline module such as power dividers consist of the circuit board with an aluminum housing which has RF connectors and is screwed together. A mylar or plastic film is laid over the top and bottom conductors for physical and mechanical protection. These modules are rarely hermetically sealed.

The screening and lot conformance testing of the Stripline module is limited by the construction methodology and materials, but should not be when the reduced criteria compromise reliability. The screening of these products has been established within each vendor's facility and the processes appear controlled.

The dissimilarities of materials and the deltas in temperature coefficients of expansion are the primary limiting factors.

The use of unpassivated chip components in the non-hermetic modules does limit reliability.

The data obtained from the SMC vendors was not as extensive as desired. SMC construction methodology does require additional work in order to ascertain comparative reliability figures for Stripline Modules. This data would be most beneficial in determining the criteria for hermeticity.

As a general observation, Stripline modules are generally larger than the MIC counterpart; it would be interesting to compare reliability data for the same in both technologies function and further compare cost. Nevertheless, Stripline products are used in airborne, ground, and shipboard systems with apparent success.

2.2 Results of the Literature Search

The literature search was conducted to augment the vendor supplied information. Appendix D contains a bibliography of the technical publications which were used. Obviously, not all the technical publications on the subjects of Stripline and MIC technologies are covered. The articles which were used described the complexity, electrical function, and, to a lesser degree, the details of the assembly and packaging of the circuits. Examination of the illustrations enabled a good approximation of the modules construction.

After reviewing the literature, it appears that both MIC and Stripline modules are produced using every conceivable component, material, process, and packaging method. Each company has developed in-process and screening procedures to assure the quality and reliability of their products consistent with applicable specifications. Sufficient safeguards are practiced within the limitations of the materials used. Again, the safeguards and material limitations must be consistent with overall product and system reliability.

2.3 Results of Industry Screening Evaluation

The screening of both MIC and Stripline Modules was of fundamental importance to the development of screening and lot conformance test methods.

The MIC vendors and systems companies screened their MIC products to variations or vendor equivalents of Method 5008, MIL-STD-883B. The SMC vendors tended to use MIL-E-16400, MIL-E-5400, and MIL-STD-202 or variations of these specifications.

2.3.1 MIC Screening

Table 2.3-1 represents the Method 5008 screening used by three MIC vendors. It is interesting to note that two companies did not preseal bake their products. One should be very concerned about the moisture levels in modules which did not have a preseal bake. Even if the module is sealed with epoxy it would require a period of time before moisture migrated through the epoxy matrix.

Table 2.3-1. MIC Vendor Variations to MIL-STD-883B

OPERATION	COMPANY A	COMPANY B	COMPANY C
INTERNAL VISUAL	Modified 2017	Modified 2017	Modified 2017
PRESEAL BAKE			1008 2 hr @ 150^{o}C
SEAL			
LEAK TEST	1014, A1 $5x10^{-8}$ atm-cc/sec		
STABILIZATION BAKE	1008, B 24 hr @ 95^{o}C	1008, B 24 hr @ 125^{o}C	1008, B 24 hr @ 125^{o}C
TEMPERATURE CYCLE	1010, B -62 to + 95^{o}C	1010, B -55 to +125^{o}C	1010, B -55 to +125^{o}C 10 cycles
ACCELERATION OR SHOCK	2001, B Y1 only 10,000 G's	2001, B Y1 only 10,000 G's	2001, D Y1 only 20,000 G's
FINE LEAK	1014, A1 $5x10^{-8}$ atm-cc/sec	1014, A1 $5x10^{-8}$ atm-cc/sec	1014, A $5x10^{-8}$ atm-cc/sec
GROSS LEAK		1014, C	1014, C
BURN-IN	1015, B 12 hr @ +85^{o}C unless longer required by contract	1015, B +85^{o}C with toroid +125^{o}C w/o toroid	1015 168 hr 125^{o}C
FINAL ELECTRICAL TEST	RF tests 25^{o}C	RF tests 25^{o}C	go-no-go 25^{o}C
EXTERNAL VISUAL	2009	2009	2009

Two MIC vendors did not perform a leak test after sealing but did perform a fine and gross leak test after screening. This appears to be a contradiction to economics in view of the rework of the seal before screening versus rejection of an initial defect after the expense of screening.

Table 2.3-1 does reflect the variations to MIL-STD-883B that are used by different vendors. In the development of the Method 5008 equivalent for MIC's, the objective was to incorporate a compromise between the variations which would be acceptable to industry and further meet the reliability objectives for the product (within each vendor's cost objectives) which would be required by the military.

Finally, the final electrical tests were all conducted at ambient 25 $^{\circ}$C at the modules RF frequency. The go-no-go tests were also conducted at RF. It is believed that DC testing is not an adequate test for the majority of MIC modules in view of the complexity of the circuit/module functions. DC tests may provide indicators of faulty or out of spec performance but the RF testing is, in most cases, mandatory to determine actual circuit/module performance.

2.3.2 Stripline Screening

Table 2.3-2 represents the approach that three SMC vendors take in the screening of their products. In the case of MIC screening, there was a reasonable consistency in the screening sequence; however, that consistency is not apparent with Stripline screening procedures.

The 5008 equivalent for Stripline was developed to be in concert with the construction of the modules (within the nonhermetic/packaged device constraint). The testing indicated in Table 2.3-2 did include modules which were not hermetically sealed and contained active and passive chip components (this contruction method is UNACCEPTABLE to the military).

Table 2.3-2. Stripline Screening

OPERATION	COMPANY C	COMPANY D	COMPANY E (MIL-STD-202)
TEMP CYCLE	$-54^{o}C$ to $95^{o}C$		
TEMPERATURE SHOCK		—54 to $125^{o}C$	Method 107, A $-55^{o}C$ to $85^{o}C$, 30 minutes at temp extremes, 5 cycles
ALTITUDE	0 to 100,000 feet	0 to 100,000 feet	Method 105, Condition D (100,000 feet)
TEMP/ ALTITUDE	$95^{o}C$ at 0 ft. to $-9^{o}C$ at 100,000 feet		
HUMIDITY	100%	95%	Method 103, Condition B (96 hrs)
VIBRATION	2G, 5-500 Hz	20G, 5-2000 Hz	Method 204 Condition B, 10-20,000 Hz, 15G Peak
MECHANICAL SHOCK	30G, 11 ms	50G	
MOISTURE RESISTANCE			Method 106
LIFE TEST			Method 108, Condition B, 250 hours
SOLDERABILITY			Method 208

It is interesting that the company which tested to MIL-STD-202 did perform life test on its militarized products. Since the modules in the majority of products were not hermetically sealed, it is interesting that humidity tests were performed. The results and yields after the test would be interesting to study.

The objective, to develop a screening and lot conformance test method for Stripline modules/products, once accomplished, would be a step in the direction that would provide valuable data on the reliability of Stripline products.

SECTION 3.0

MIC AND STRIPLINE SCREENING

AND

LOT CONFORMANCE TESTING

3.0 METHOD 5XXX EQUIVALENT FOR MIC AND STRIPLINE

3.1 Method 5008 Equivalent for MIC's

Method 5008 equivalent for Microwave Integrated Circuits (MIC) was successfully developed to achieve an optimum set of screening and quality conformance tests for hermetically sealed MIC's. The proposed method follows that same general format as exists for Method 5008, MIL-STD-883B but differs in content in three primary areas. The differences are:

a. Preassembly evaluation criteria for packages and substrates

b. Expansion of screening criteria

c. Revision of Groups A, B, and C quality conformance criteria

3.1.1 Preassembly Package and Substrate Evaluation

Preassembly package and substrate evaluation was extensively revised into five specific subgroups, the first three of which address package integrity and the remaining subgroups address substrate evaluations. Referring to Figure 3.1-1, and subgroup 1 requires evaluation of the package's physical dimensions dependent on circuit functions and the package constraints specified by an applicable detail specification. Lead integrity tests are intended to evaluate dc feedthru or leads which are an integral part of the package. Subgroup 2 addresses thermal and mechanical stresses with respect to substrate-to-package attachment integrity and subgroup 3 is intended to evaluate the package's environmental integrity when exposed to a corrosive atmosphere or high humidity. Subgroups 4 and 5 are substrate related evaluations primarily addressing metallization.

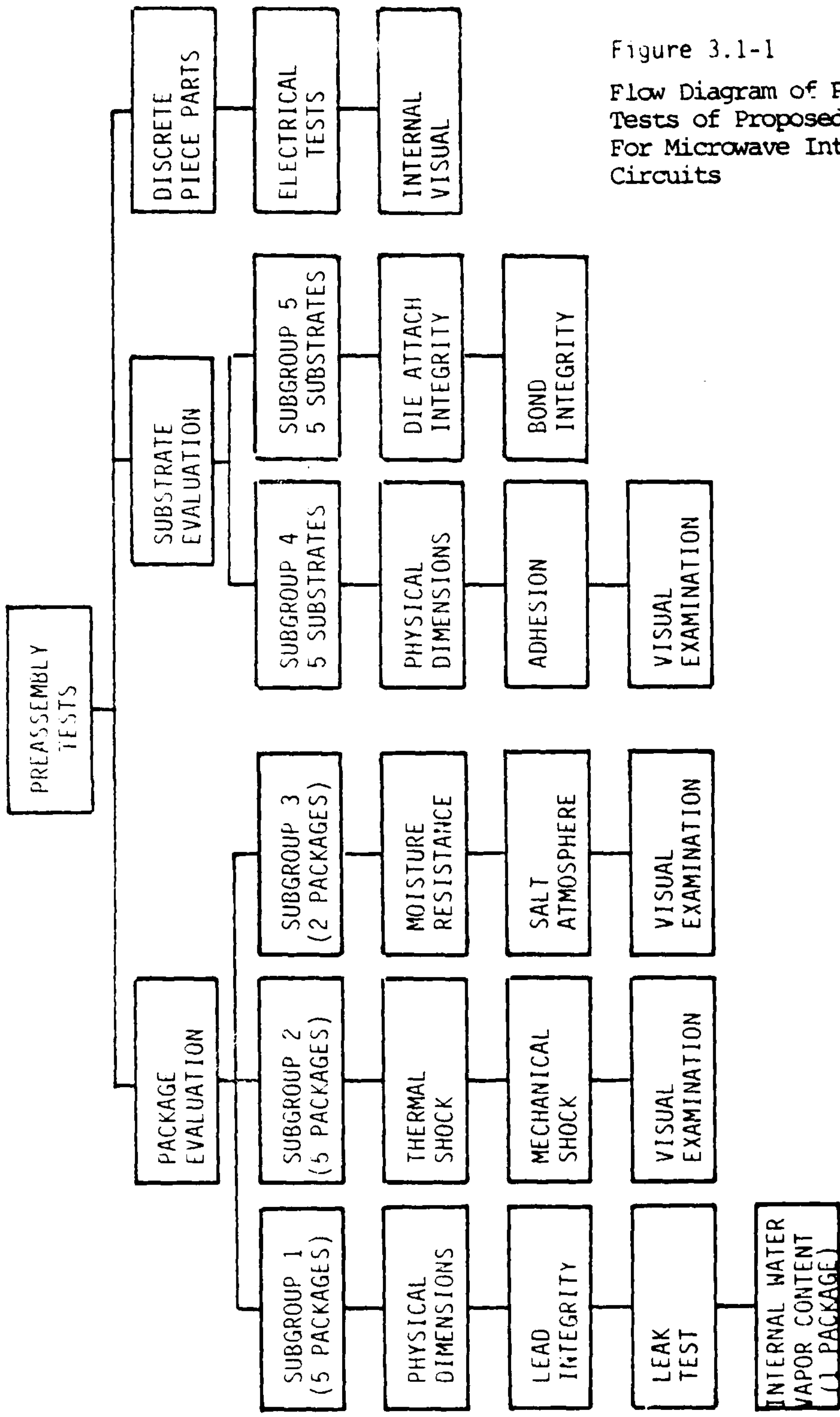


Figure 3.1-1

Flow Diagram of Preassembly Tests of Proposed Method 5XXX For Microwave Integrated Circuits

3.1.2 Screening Criteria

Referring to Figure 3.1-2, screening sequences follow the criteria of existing method 5008. Primary differences are the examination of internal visual criteria (described in more detail in Section 4.0), revision of thermal and mechanical stress levels, and expansion of the burn-in requirements to provide guidelines for DC, RF and digital stress criteria, during burn-in, dependent on the circuit's intended usage and power handling limitations.

3.1.3 Quality Conformance Criteria

Referring to Figure 3.1-3, Group A tests specifically address electrical requirements at minimum, ambient, and maximum temperatures.

3.2 Method 5XXX for SMC

Method 5008 equivalent for SMC was specifically developed to achieve an optimum set of screening and quality conformance tests for non-hermetically sealed microwave Stripline circuits. The proposed method follows the same general format as existing method 5008, of MIL-STD-883B but differs in content in four primary areas as follows:

a. Limitations on the use of unpackaged discrete component piece parts

b. Preassembly evaluation criteria for packages and circuit boards

Figure 3.1-2. Flow Diagram of Screening Tests of Proposed Method 5XXX For Microwave Integrated Circuits

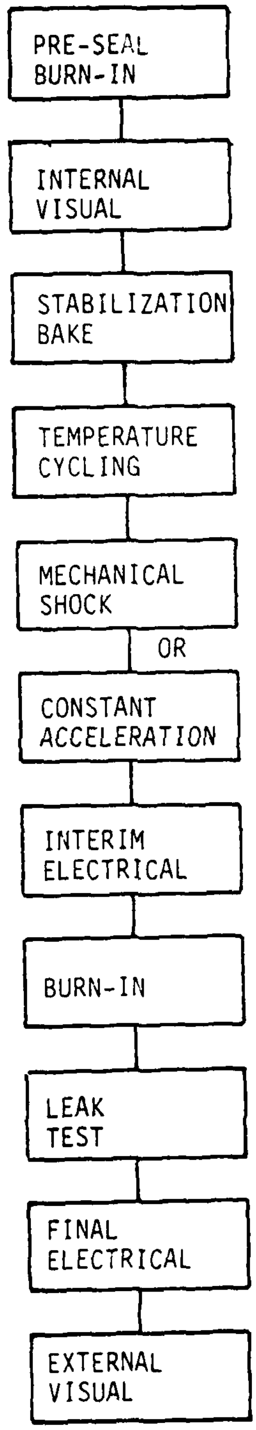
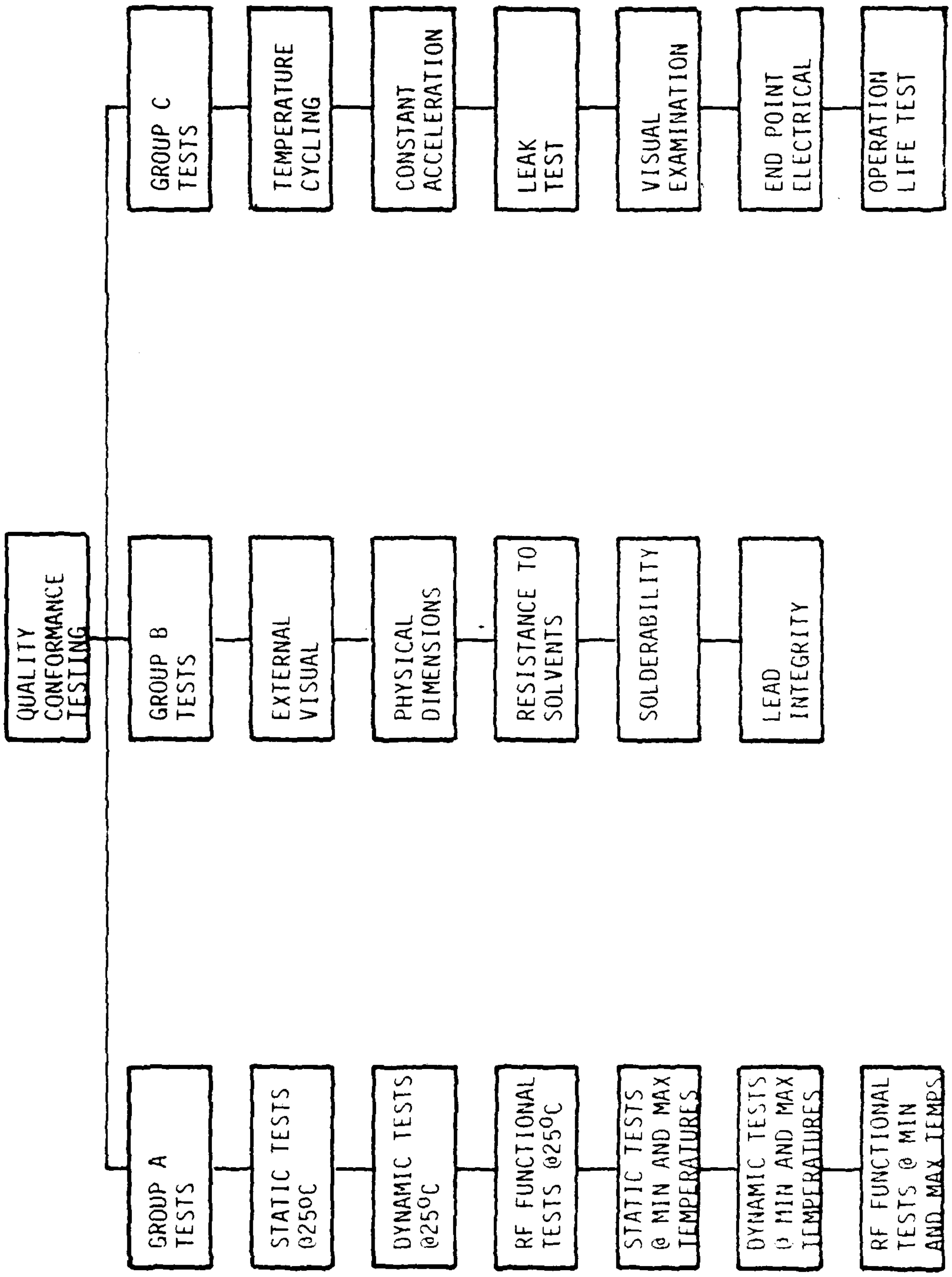


Figure 3.1-3. Flow Diagram of Quality Conformance Testing of Proposed Method 5XXX For MIC's



c. Expansion of screening criteria

d. Revision of and quality conformance criteria

3.2.1 Discrete Component Piece Parts

The proposed method requires discrete active circuit components to be hermetically packaged and passivation protection of all passive chip components. No additional limitations on the use of circuit components and materials was deemed necessary other than to reiterate the requirements for adequate procedures to identify and reject all noncompliant parts and materials prior to assembly and packaging.

3.2.2 Preassembly Package Evaluation

Preassembly package evaluation was extensively revised into five specific subgroups, the first three of which address package integrity and the remaining subgroups to circuit board/substrate evaluation. Referring to Figure 3.2-1, subgroup 1, requires evaluation of the package's physical dimensions dependent on circuit function and the package constraints specified by an applicable detail specification. Lead integrity tests are intended to evaluate DC feedthru or leads which are an integral part of the package. Subgroup 2 addresses thermal and mechanical stresses with respect to circuit board/substrate-to-package attachment integrity and subgroup 3 is intended to evaluate the package's environmental integrity when exposed to a corrosive atmosphere or high humidity.

3.2.3 Preassembly Circuit Board Evaluation

Subgroups 4 and 5 are circuit board/substrate related evaluations primarily addressing adhesion of the conductor pattern to circuit board dielectric/plating to conductor pattern, solderability of the circuit board and bond integrity.

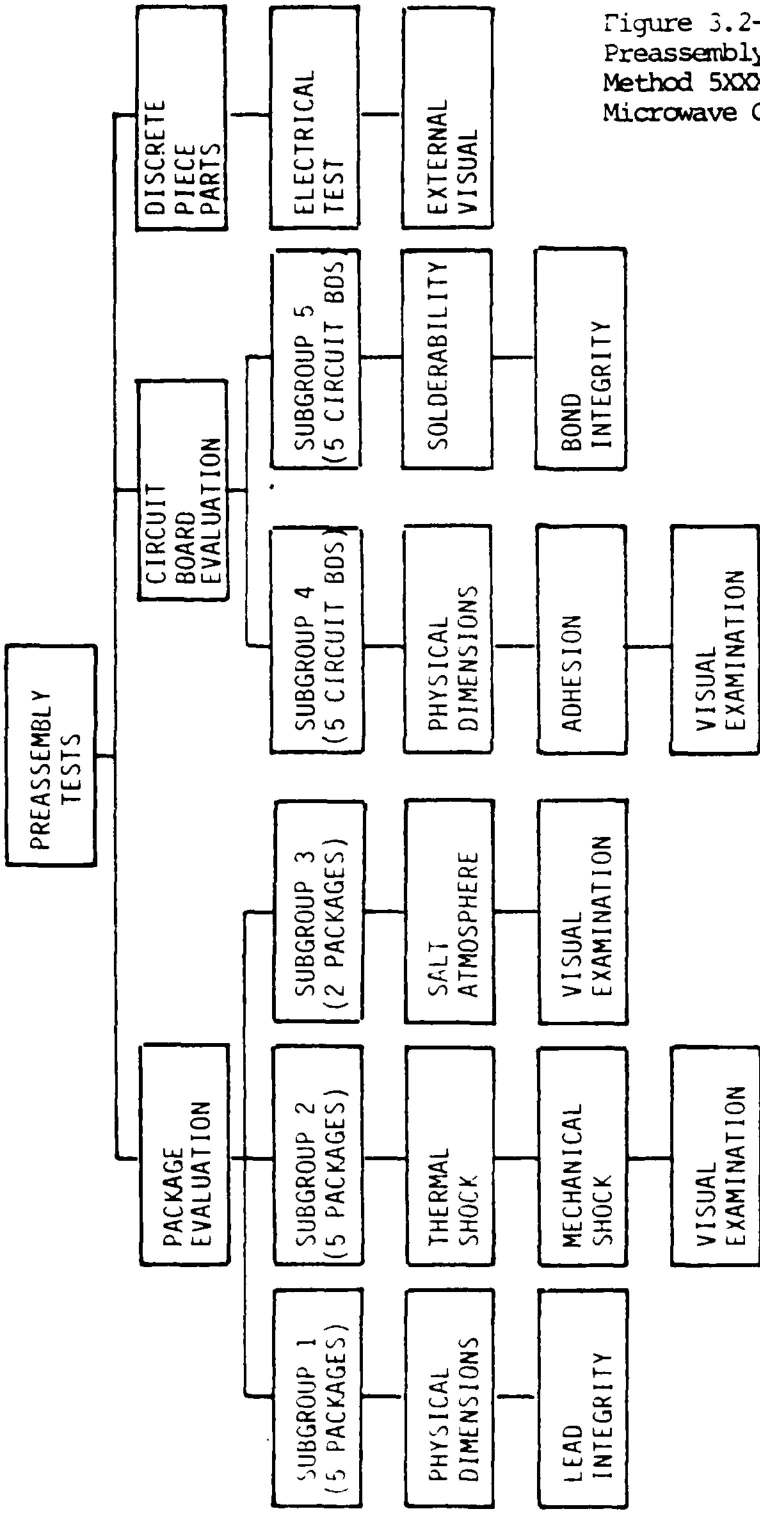


Figure 3.2-1. Flow Diagram of Preassembly Tests of Proposed Method 5XXX For Stripline Microwave Circuits

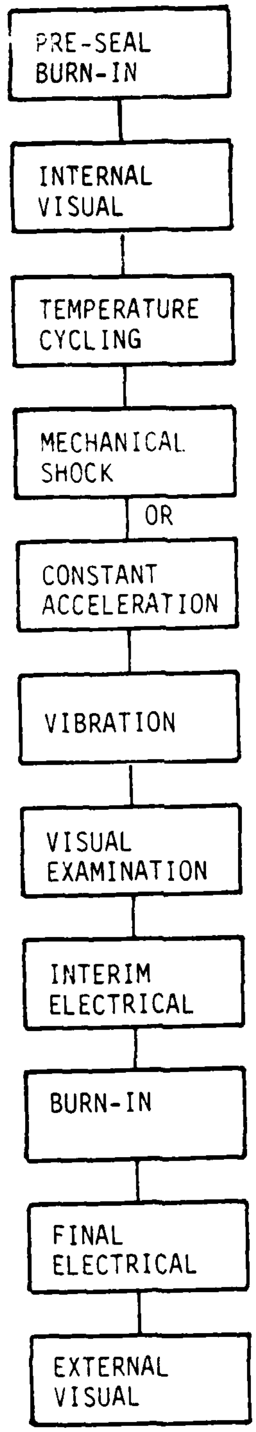
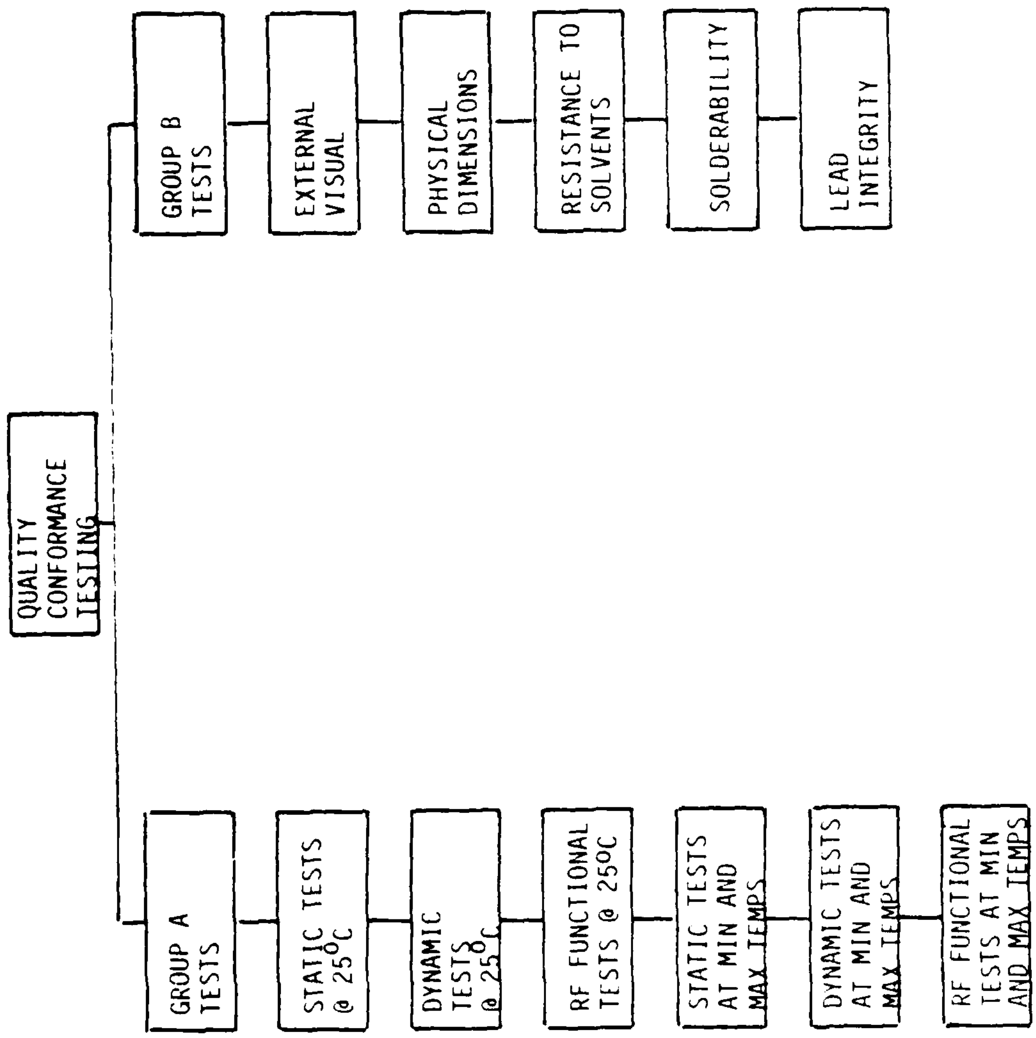


Figure 3.2-2.
Flow Diagram of Screening Tests of Proposed Method 5XXX For Stripline Microwave Circuits

Figure 3.2-3. Flow Diagram of Quality Conformance Testing of Proposed Method 5XXX For Stripline Microwave Circuits



3.2.4 Screening Criteria

Referring to Figure 3.2-2, screening sequences follow the criteria of existing method 5008. Primary differences are the development of a completely new set of internal visual criteria for SMC's (described in more detail in Section 4.0), revision of thermal and mechanical stress levels and expansion of the burn-in requirements to provide guidelines for DC, RF and digital stress criteria during burn-in, dependent on the circuit's intended usage and power handling limitations.

3.2.5 Quality Conformance Criteria

Referring to Figure 3.2-3, Group A tests specifically address electrical requirements at room ambient and maximum and minimum temperatures. Group B tests address visual, mechanical, resistance to solvents, solderability, and lead integrity requirements.

3.3 Electrical Test Requirements

Since the impacts of cost and performance must be carefully viewed with respect to electrical test requirements, primary emphasis must be on the testing of individual circuits that make up the MIC or SMC module, preseal module testing, and electrical test as required by the test method and/or the applicable detail specification.

One must recognize that the MIC or SMC individual circuits may be an element of the whole module performance much like a waveguide or cavity. Testing circuits outside of the module may not be entirely representative of the integrated module performance. Also, the metallic lid of the module must generally be in place and electrically connected to the module to achieve required preseal test results.

The question of what constitutes appropriate test of MIC or SMC, must be answered with respect to the completed module performance and the meaning/interpretation of test data at the individual circuit level. The frequency of the circuit will be a prime consideration, the test fixture must be a consideration, the capability to correlate individual circuit performance to completed module performance is also required. Simply, each module design must be considered on a separate basis and electrical test requirements should be tailored to meet the required performance.

It is practical to develop general guidelines for DC and RF test that can be conducted in order to reduce rework and comply with the proposed testing that is contained in the proposed Method 5008 equivalents for MIC's and SMC's.

For purpose of developing a test rationale MIC and SMC modules are considered as microwave modules. It is recognized that the construction methods will generate variations to the testing plan and should be part of the detail specification.

3.3.1 MIC and SMC Module Testing Philosophy

The sequence of testing that will be discussed in this section is in general use in the MIC and Stripline industries. This philosophy is based upon economic realities associated with complex, highly integrated MIC and SMC modules. The testing that is proposed and the sequence is as follows:

3.3.1.1 Preseal Burn-in: this optional test shall be performed at 125 ^{o}C, +5 ^{o}C -0 ^{o}C for a maximum of 48 hours, +8 hours - 0 hours. Stresses shall be induced by the application of dc bias. DC bias levels to be specified in the applicable detail specification. Pre-seal burn-in need not be performed if the devices used in the module construction were burned-in to this criteria prior to assembly in the module. MIL-STD-883B, Method 1015 curves are an acceptable alternate method for establishing time/temperature for preseal burn-in.

3.3.1.2 Postseal Burn-in: this shall be performed at 125 $^{\circ}$C, +5 $^{\circ}$C -0 $^{\circ}$C for a minimum of 160 hours, + 8 hours, -0 hours. Stresses shall be induced by the application of dc power. DC power levels to be specified in the applicable detail specification.

NOTE: Since preseal burn-in is optional the total burn-in must not be less than 160 hours unless otherwise specified in the applicable detail specification. Other time-temperature equivalence may be determined from Method 1015, Figure 1015, MIL-STD-883B to meet the construction limitations of the particular module construction.

3.3.1.3 Unless otherwise specified, the following criteria shall be utilized during burn-in:

3.3.1.3.1 Small signal devices (100 milliwatts or less) shall be stressed by DC power.

3.3.1.3.2 Large signal power devices (greater than 100 milliwatts) shall be stressed by applying RF signal excitation consistent with normal operation and appropriate dc power levels.

3.3.1.3.3 RF devices with digital control shall be stressed by exercising the digital dynamics in addition to appropriate applications of power as specified in 3.3.1.3.1 and 3.3.1.3.2 above.

3.3.2 Final Electrical Measurements shall assure that the MIC or Stripline modules tested meet the electrical requirements of the applicable detail specification and shall include, as a minimum, all parameters, limits, and conditions of test which are specifically identified in the detail specification or drawing as final electrical test requirements. Electrical test shall be conducted at the required temperature extremes including ambient temperature and the data recorded for this test.

3.3.3 Clarification

The many variations of construction methods, materials, components, tuning techniques, and package configurations do not lend well to the establishment of standard burn-in and electrical test requirements. The time/temperatures for burn-in may be established in accordance with MIL-STD-883B, Method 1015 curves. The burn-in electrical conditions must be established in accordance with active and passive component thermal and electrical limitations.

Because of the module design variations, it is more applicable to require that a burn-in test plan be approved by the procuring agency for the specific module being tested. We have attempted to establish testing guidelines in the proposed test methods but these fall short of the objective to minimize exceptions. At least, options are available for consideration and with respect to burn-in and electrical test requirements.

SECTION 4.0

PRESEAL VISUAL CRITERIA FOR MICROWAVE INTEGRATED CIRCUITS

AND

STRIPLINE MICROWAVE CIRCUITS

4.0 PRESEAL VISUAL CRITERIA FOR MIC AND STRIPLINE

4.1 Method 2017.1 Update for MIC's

The internal visual criteria contained in Method 2017.1 of MIL-STD-883B does not cover many of the construction methods utilized in microwave integrated circuits and therefore an update to the exact method was desirable. The proposed expansion to method 2017.1 includes the following:

a. Parallel plate chip capacitor criteria

b. Interdigitated and deposited capacitor criteria

c. Thin and thick film void and pin hole expansions to existing criteria. The illustrations which are contained in the up-dated Method 2017 incorporate such defects as scratches in a resistor which result from handling, scratches in masks which are reproduced in the resistor films; and, in general, improved illustrations of voids and pin holes observed in both thin film and thick film patterns.

d. Chip component orientation versus substrate connector and feedthru center contact

e. Connector and feedthru center contact orientation and solder joint acceptance

f. Various updates throughout this method

4.1.1 Parallel Plate Chip Capacitors

The proposed addition incorporates criteria for peeling of top and bottom metallization, metallization smearing, cracks in the dielectric and metallization extending around the edges of the capacitor.

4.1.2 Interdigitated Capacitors

Interdigitated capacitor criteria includes scratches and voids in the metallization and bridging of metallization.

4.1.3 Thin and Thick Film Void and Pinhole Criteria

The proposed addition incorporates additional void criteria and develops criteria for pinholes which reduce the resistor width or area.

4.1.4 Chip Component This addition establishes the criteria for chip parallelism to substrate surface.

4.1.5 Connector and Feedthru Center Contact Soldering Criteria

This section was developed to provide criteria for center contact orientation and solder joint visual acceptance.

4.1.6 Various Updates to the Method

Method 2017.1, MIL-STD-883B was thoroughly reviewed and various sections were updated as necessary.

4.2 Method 2XXX for Stripline

Method 2XXX equivalent for microwave Stripline circuits was developed to provide internal visual inspection criteria specifically addressing those areas unique to Stripline construction methods. Since Stripline microwave circuits represent a combination of printed circuit board and hybrid construction techniques utilizing chip components, packaged devices, soldered components and wires, the development of a new method separate from existing method 2017.1 was desirable. The proposed method follows the same general format as exists, Method 2017.1, MIL-STD 883B and contains the following key areas:

a. Hermetically sealed active devices

b. Passive chip components

c. Basic current board visual criteria

d. Solder and organic polymer component mounting

e. Solder and organic circuit board to package attachment

f. Connector and feedthru center contact soldering criteria

g. Wire bond criteria

4.2.1 Hermetically Sealed Active Devices

The proposed method requires discrete active components to be hermetically packaged, JANTX OR Class B. The proposed method addresses the criteria for internal visual inspection which will normally be conducted by the component supplier. The criteria is identical to the requirement specified in Method 2017.1.

4.2.2 Passive Chip Components

Criteria contained within this section is identical to the requirements specified in Method 2017.1.

4.2.3 Basic Circuit Board Visual Criteria

Basic circuit board visual criteria was developed including criteria for undercutting, conductor separation, conductor overhang, voids and scratches.

4.2.4 Solder and Organic Polymer Component Mounting

The proposed method includes criteria from existing method 2017.1 and was expanded to include chip component parallelism to circuit board, component orientation and excess solder and/or organic polymer material.

4.2.5 Solder and Organic Polymer Circuit Board Attachment

This section follows the same general requirements as existing Method 2017.1.

4.2.6 Connector and Feedthru Center Contact Soldering Criteria

This section was developed to provide criteria for center contact orientation and solder joint visual acceptance.

4.2.7 Wire Bond Criteria

Wire bond criteria follows the same requirements contained in Method 2017.1.

SECTION 5.0

MICROWAVE INTEGRATED CIRCUIT

AND

STRIPLINE MICROWAVE CIRCUIT TUNING

5.0 RF TUNING METHODS AND RELIABILITY

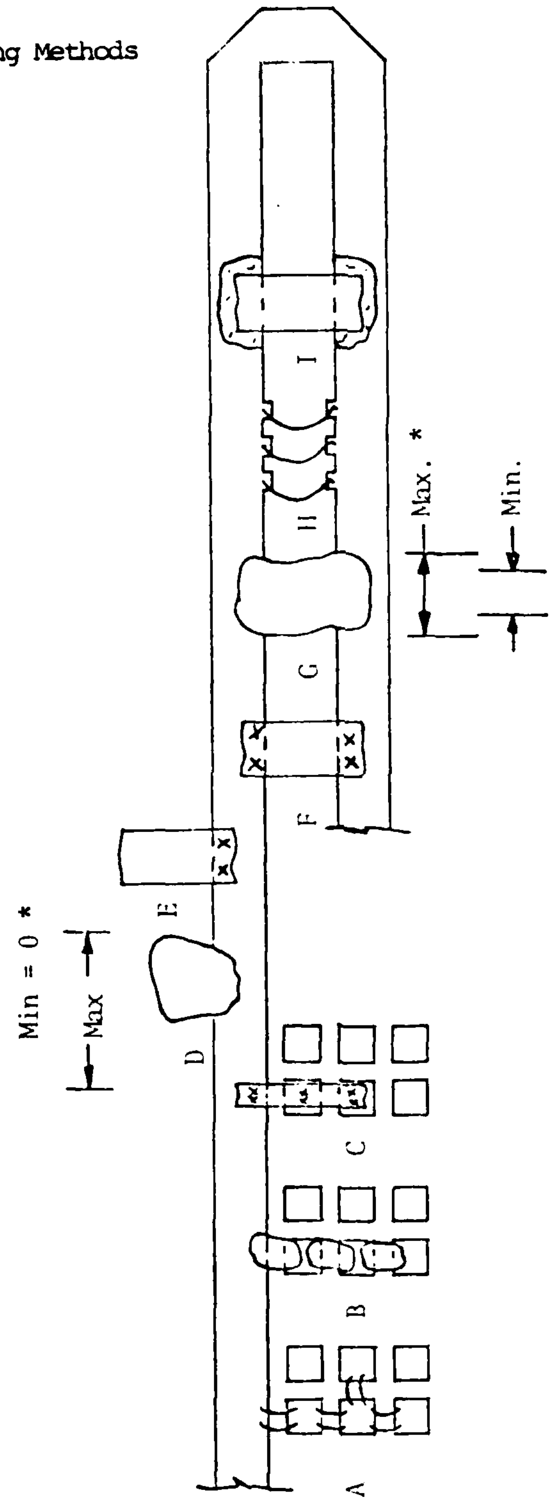
The primary industry methods for RF electrical tuning of MIC and Stripline circuits can be divided into three categories: additive; that is, the addition of electrical length by physical means, subtractive; that is, the substraction of electrical length by physical means, and oriented; that is, the deformation or movement of wires.

There are also methods used to select components during the testing of modules which are not tuning methods. The 'toothpick' capacitor or resistor is one method and is simply a capacitor or resistor 'glued' to a toothpick or any non-conductor material. Electrical contact is made by compression and the required component value can be determined by selecting the resistor or capacitor value.

5.1 Additive Tuning

This method of tuning includes techniques to increase the length, width, or area of a conductor path. Primary methods include wire bonding to adjacent conductor areas, soldering or epoxying conductive foil bridges to adjacent conductor areas, soldering or epoxying 'stubs' over insulating areas, and applying conductive epoxy shorting conductor areas or increasing conductor areas. Figure 5.1-1 illustrates these methods of tuning. Method 2017.1 MIL-STD-883B has criteria for the visual inspection of these tuning methods but the interpretation may lead to confusion. For example, a metal stub soldered to a conductor area is not affixed to the substrate, epoxy used to short conductor areas may be considered a 'smear', and wire bonds which are generally flat to achieve electrical tuning do not meet the contour requirements (i.e., parabolic in shape).

Figure 5.1-1.
Additive Tuning Methods



A, H Wirebond to adjacent conductor
B, G Conductive organic compound to adjacent conductor
C, F Welded ribbon to adjacent conductor
D Conductive organic "STUB" over insulating area
E Welded ribbon stub over insulating area
I Soldered ribbon bridge

* Required in applicable drawings

Visual inspection is hindered by a very important factor: each tuning area may and most probably will be different in form and shape from circuit to circuit. Comparisons to a dimensional drawing for tolerance would be virtually impossible. This hinderance can be overcome by using minimum/maximum limits for describing the boundaries of the tuning components in the detail drawings. Method 2017.1 should also add a separate criteria for tuning to be in concert with accepted practices.

It has been observed that the tuning adjustments performed during electrical testing of a MIC or Stripline circuit are sensitive to thermal and mechanical screening. Any rework of the tuning elements must be verified by electrical testing.

The reliability of the additive techniques require additional data. For example, the adherence of conductive polymers to dielectric substrate materials must be tested through the screening sequence such that there would be no loss of adherence (obviously, loss of adherence would result in eventual failure). The motion of soldered or conductively epoxied stubs during shock and vibration testing could result in fatiguing of the attachment joint and a resultant failure.

Suffice it to say that these tuning methods are commonly used but insufficient data exist to determine the reliability as a function of screening.

5.2 Subtractive

Another generally used method of tuning adjustment includes technique for removal of conductor pattern areas. The methods of material removal are usually limited to thermal (laser) or abrasive (sand blasting, knives, carbide or diamond scribes). Chemical milling (etchings) are not generally used on assembled MIC or Stripline circuits during electrical tuning, though they are occasionally used during substrate fab and rework. Methods of subtractive tuning are described in Figure 5.2-1.

Again, the interpretation of the visual criteria of Method 2017.1, MIL-STD-883B can lead to difficulties. For example, scribing a conductor line open will result in smearing of the metallization and minor damage to the underlying substrate. Because of the fine line geometries, there is often minor damage to adjacent line which may not meet the acceptance criteria for metallization scratches.

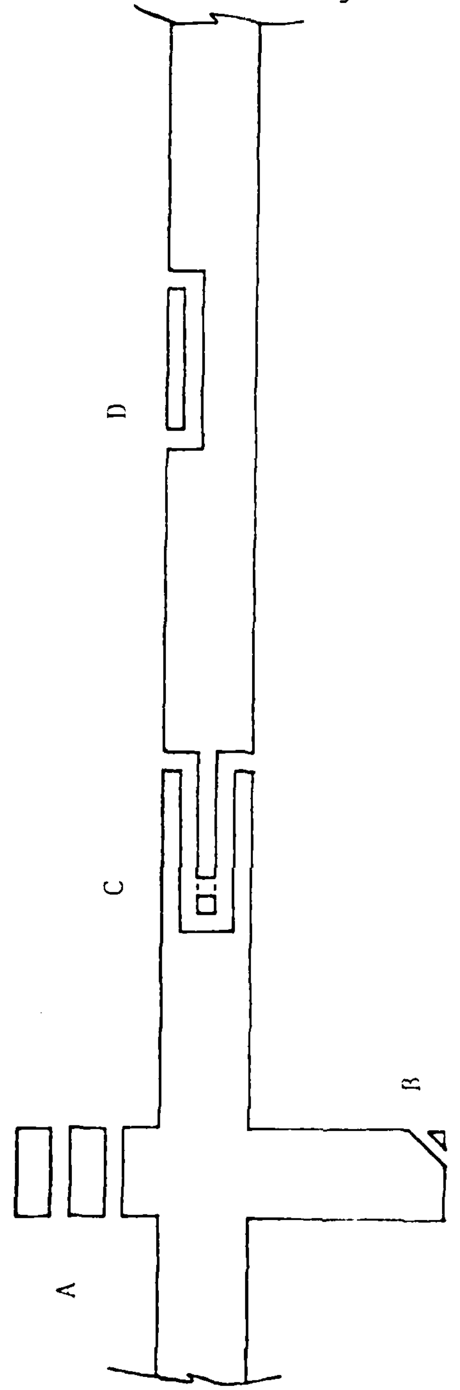
As in the case of additive tuning, visual inspection is hindered by the same deviations noted with the additive tuning methods. Tuning methods will cause a difference between the actual circuit and detailed drawings. Minimum/maximum limits must be established that would satisfy reliability and performance constraints and those constraints added to the applicable drawings. Reworked or retuned circuits/modules would require verification by electrical testing.

The reliability of the subtractive tuning methods is a serious concern. Will smeared metallization detach? Will non-conductive material (i.e., from damage to the substrate) detach? The subtractive tuning method used must be evaluated to prevent failures associated with the method used for this tuning. Again, data must be generated and in-process safeguards established to prevent loose particles (conductive or non-conductive) in the final, sealed product.

5.3 Oriented

This method of tuning relies on the physical deflection of

Figure 5.2-1. Subtractive Tuning Methods

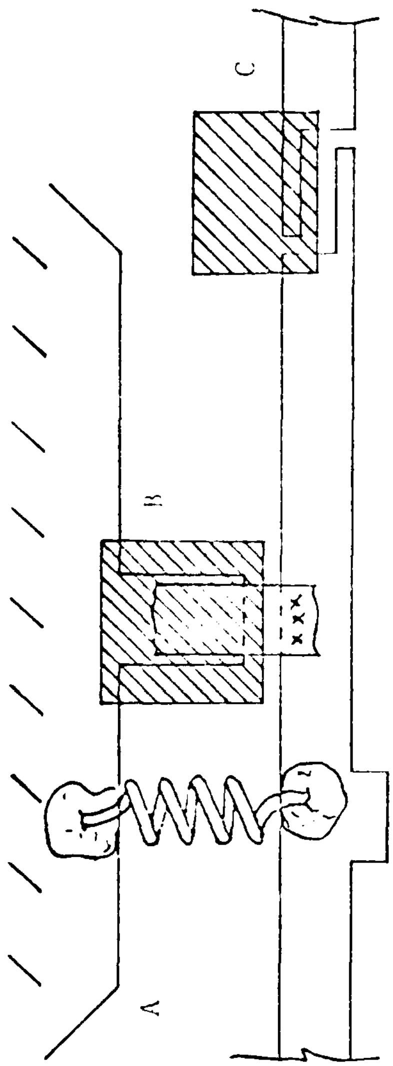


A Abrasive/thermal cuts to change length of "STUBS"
B Abrasive/thermal cuts to change general area
C Abrasive/thermal cuts to change general length
D Abrasive/thermal cuts to change general width

conductors or insulators to modify mutual coupling (magnetic or capacitive). Orientation of conductors or insulators is reversible and, therefore, very appealing for use in circuits which require close tolerances, or those having parameter variations. The reversibility is also the fundamental negative aspect because it compromises stability over the environment. Figure 5.3-1 depicts commonly used tuning methods using orientation. Many varieties of variable capacitance elements, as component trimmers, are available and will not be detailed here. Visual inspection of this type of tuning is extremely difficult due to the movable circuit elements obscuring view, but this is an area that must not be overlooked. Reliability can be seriously affected because of mechanical or environmental overstress during deformation of the tuning element. The primary concerns are gap widths, foreign material, cracks in the bonding material, and general mechanical integrity.

Stability of the component values may be compromised during the tuning operations due to unrelieved stresses. A mandatory temperature cycle from room ambient to the maximum specified temperature and back to room ambient temperature neutralizes these stresses and is a preferred process step during the test and tune portion of assembly. This temperature cycling must be performed before the module is sealed. The stress characteristics will vary with the material used and must be considered when using this method of tuning. The degree of stress induced in the wire material is human related and would

Figure 5.3-1. Orientative Tuning Methods



A Deformable wire for magnetic mutual coupling change
B Deformable ribbon for capacitive mutual coupling change
C Movable dielectric block for capacitance change

therefore, very appealing for use in circuits which require close tolerances, or those having large parameter variations. The reversibility is also the fundamental negative aspect because it compromises stability over the environment. Figure 5.3-1 depicts commonly used tuning methods using orientation. Many varieties of variable capacitance elements as components trimmers are available and will not be detailed here. Visual inspection of this type of tuning is extremely difficult due to the movable circuit elements obscuring view, but this is an area that must not be overlooked. Reliability can be seriously affected because of mechanical or environmental overstress during deformation of the tuning element. The primary concern is gap widths, foreign material, cracks in the bonding materials and general mechanical integrity.

Stability of the component values may be compromised during the tuning operations due to unrelieved stresses. A mandatory temperature cycle from room ambient to the maximum specified temperature and back to room ambient temperature neutralizes these stresses and is a preferred process step during the test and tune portion of assembly. This temperature cycling must be performed before the module is sealed. The stress characteristics will vary with the material used and must be considered when using this method of tuning. The degree of stress induced in the wire material is human related and would be difficult to control. Application of non-conductive material would minimize stress relieved detuning but another problem would be created by capacitive detuning associated with the non-conductive material.

In brief, the thermal and mechanical properties of the materials being used must be understood relative to the environment to which the module will be exposed.

SECTION 6.0

MIL-M-38510, APPENDIX G EVALUATION

6.0 SUMMARY

The workmanship and rework requirements of 3.7 and 20.5 of Appendix G, MIL-M-38510 were found to be applicable to MIC and Stripline circuits with several key exceptions. It must be noted that this evaluation was conducted separately from the development of MIC and Stripline Screening and Lot Conformance test methods.

6.1 The Evaluation

6.1.1 The rework limitations of MIL-M-38510 do not apply to tuning methods that were described in Section 5.0.

6.1.2 Replacement of a functional circuit contained on a removable substrate in a module does not constitute a rework operation.

6.1.3 MIL-M-38510 does not permit delidding a sealed module if a MIC module is defined as a hybrid package; however, the economics of this prohibition would be catastrophic to the MIC industry. Delidding must be permitted and it is recognized that the reseal operation should be documented. The most appropriate approach to delidding and reseal would be that the process be approved by the procuring agency.

6.1.4 The limitation of 2 rework cycles does not apply to MIC or Stripline modules which are multisubstrate. The restriction should be removed provided that all inspections, tests, screening and acceptance test criteria of this specification are successfully completed.

It becomes obvious that unlimited rework would have natural limitations because of the inherent failures after 'too many' screening and burn-in cycles.

Economics are a reality but should not be cause for reducing the module's reliability. It is, once again, a trade-off.

Rework of MIC and Stripline modules and the commensurate affects on reliability will remain an open issue until data is generated on the affects.

SECTION 7.0

DYNAMIC AND THERMAL STRESS ANALYSIS OF MIC AND STRIPLINE CONSTRUCTION METHODS

7.0 INTRODUCTION

The purpose of this investigation was to determine the ability of six MIC and stripline modules to withstand various dynamic and thermal cycling environments. The dynamic environments included 24 Grms random vibration; 3000g, 3 msec shock; and 10,000g constant acceleration. The thermal cycling environment consisted of 100 thermal cycles with temperature limits of -65^{o} C and + 125^{o} C. The STARDYNE finite element computer program was used to determine module dynamic behaviour. The program computed module resonant frequencies, dynamic response, and dynamic stresses. Where applicable, hand calculations were used to supplement the finite element analysis. The ANSYS finite element computer program was used to determine module thermal stresses resulting from the thermal cycling environment. Ultimate margins of safety were calculated to assess each module's ability to survive the above environments. These margins of safety formed the basis for various conclusions and recommendations concerning module design. Recommendations for future analysis were also made.

7.1 Results

The results of the STARDYNE and ANSYS analysis by module are presented in eight tables in this section.

These tables are needed for reference as each module, lead, connector, and substrate are discussed.

The results cover a defined environment and the data can only be extrapolated to less stringent environments. The extrapolation is not necessarily simple; one must carefully understand the resonant frequencies; nevertheless, this work is only the groundwork for refining the computer analysis of MIC and Stripline modules.

Table 7.1-1. Module #1 Vibratory Modes

Mode Number	Natural Frequency (Hz)	Type of Motion
1	2,574	Cover Plate Bending Mode
2	2,623	Cover Plate Bending Mode
3	2,655	Cover Plate Bending Mode
4	2,902	Cover Plate Bending Mode
5	2,906	Cover Plate Bending Mode
6	3,491	Not Extracted (Probably Cover Plate Bending Mode)
7	8,208	.50 in x 1.00 in Substrate First Plate Bending Mode
8	10,153	.50 in x 1.50 in Substrate First Plate Bending Mode
9	13,066	.50 in x 1.00 in Substrate Second Plate Bending Mode
10	14,946	.50 in x 1.50 in Substrate Second Plate Bending Mode
11	20,868	.50 in x 1.50 in Substrate Third Plate Bending Mode
12	23,986	Not Extracted (Probably .50 in x .50 in Substrate First Plate Bending Mode)

Table 7-1.2. Module #1 Dynamic Stresses

Dynamic Environment	Component Analyzed	Dynamic Deflection (in)	Dynamic Stress (psi)	Margin of Safety[1]
24 G_{rms} Random Vibration	Substrate	1.23×10^{-4}	28	2,549
↓	Cover		37	1,215
↓	Module		.93	48,386
3,000g, 3 msec Shock	Substrate	4.30×10^{-3}	643	108
↓	Cover		991	44.40
↓	Module		22	2,044
10,000g Acceleration	Substrate	1.40×10^{-2}	1,308	52.51
↓	Cover		3,247	12.85
↓	Module		311	144
10,000g Acceleration	Substrate Lead	1.08×10^{-4}	340	54.88
↓	Feedthru Lead	1.31×10^{-2}	154,200	-.88
40 psi Spring Pressure Plus 10,000g Acceleration	Substrate	4.20×10^{-3}	29,100	1.40
	Substrate Mounting Screws	1.08×10^{-6}	5,200	14.76

1. Margin of Safety (M) is defined as: $M = \frac{\text{Ultimate Strength}}{\text{Calculated Stress}} - 1$

Table 7.1-3. RF Connector Thermal Stresses as Installed

Component Analyzed	Material	Temperature (° C)	Stress (psi)	Margin of Safety[1]
Female Connector	Beryllium Copper	125	18,240	2.28
Insulator	Teflon		1,725	.44
Outer Case	Stainless Steel		27,050	1.77
Male Connector	Brass		6,020	5.14
Module	Aluminum		15,250	1.95
Kovar Shell	Kovar		37,900	.97
Glass	7052 Glass		13,650	-.49

Unrestrained

Component Analyzed	Material	Temperature (° C)	Stress (psi)	Margin of Safety[1]
Female Connector	Beryllium Copper	125	18,200	2.29
Insulator	Teflon		1,980	.26
Outer Case	Stainless Steel		8,150	8.20
Male Connector	Brass		14,010	1.64
Kovar Shell	Kovar		28,270	1.65
Glass	7052 Glass		6,100	.14

1. Margin of Safety (M) is defined as: $M = \frac{\text{Ultimate Strength}}{\text{Calculated Stress}} - 1$

Table 7.1-4. DC Feedthru Thermal Stresses

Component Analyzed	Material	Temperature (° C)	Stress (psi)	Margin of Safety[1]
Wire	Alloy 52	125	10,440	5.22
Epoxy Seal	2651-MM Epoxy	-65	2,470	1.83
Ceramic	Barium Titanate	125	8,730	.34
Hermetic Seal	9010 Glass	125	8,990	-.23
Case	C1213 Steel	125	24,240	2.01
Solder	62% Tin Solder	125	13,660	-.56
Module	6061-T6 Aluminum	125	11,900	2.78

Unrestrained`

Component Analyzed	Material	Temperature (° C)	Stress (psi)	Margin of Safety[1]
Wire	Alloy 52	125	4,680	12.88
Epoxy Seal	2651-MM Epoxy	-65	2,280	2.07
Ceramic	Barium Titanate	125	5,220	1.24
Hermetic Seal	9010 Glass	125	5,390	.29
Case	C1213 Steel	125	18,930	2.85

1. Margin of Safety (M) is defined as: $M = \frac{\text{Ultimate Strength}}{\text{Calculated Stress}} - 1$

Table 7.1-5. Modules #2, 3, 4 Dynamic and Thermal Stresses

Module	Component Analyzed	Loading	Stress (psi)	Margin of Safety[1]
2	Substrate	40 psi spring pressure plus 10,000g acceleration	12,400	5.61
	Substrate	.007 spring deflection plus 10 000g acceleration	64,500	-.89
3	Epoxy Joint	10,000g acceleration	90	21.22
	Welded Joint		90	832.33
	Epoxy Joint	-65 $^{\circ}$F Thermal	6,340	-.69
4	Substrate Screws	10,000g acceleration	2,430	1.06
	Substrate		6,290	10.12

1. Margin of Safety (M) is defined as: $M = \frac{\text{Ultimate Strength}}{\text{Calculated Stress}} - 1$

Table 7.1-6. Module #5 Lead Dynamic Stresses

Loading	Horizontal Projection (in)	Vertical Projection (in)	Length (in)	Stress (psi)	Margin of Safety[1]
10,000g Acceleration ↓	.450	.166	.480	706,600	-.974
	.080	0	.080	20,900	-.091
	.040	.166	.170	22,800	-.167
	.040	.040	.056	7,510	1.530

1. Margin of Safety (M) is defined as: $M = \frac{\text{Ultimate Strength}}{\text{Calculated Stress}} - 1$

Table 7.1-7. Module #5 Substrate Material Comparison

Structural

Material	Young's Modulus (psi)	Weight Density (lb/in^3)	Strength-to-Weight Ratio (in)	Ultimate Strength (psi)	Rank
G-10	20×10^6	.065	307×10^6	35,000	1
Teflon	$.70 \times 10^6$	.079	8.9×10^6	20,500	2
G-2	12×10^6	.054	222×10^6	11,000	3

Thermal Stresses

Component Analyzed	Material	Stress (psi)	Margin of Safety[2]	Rank
Module	Aluminum	770	57.44	
Solder	62% Tin Solder	2,680	1.28	
Substrate	Teflon	3,290	5.23	1
Module	Aluminum	2,340	18.23	
Solder	62% Tin Solder	4,300	.42	
Substrate	G-10	7,410	3.72	2
Module	Aluminum	850	51.94	
Solder	62% Tin Solder	2,630	1.32	
Substrate	G-2	9,520	.15	3

1. Strength-to-Weight Ratio (R) is defined as: $R = \frac{\text{Young's Modulus}}{\text{Weight Density}}$

2. Margin of Safety (M) is defined as: $M = \frac{\text{Ultimate Strength}}{\text{Calculated Stress}} - 1$

Table 7.1-8. Module #6 Thermal Stresses

Component Analyzed	Material	Temperature ($^{\circ}$ C)	Stress (psi)	Margin of Safety[1]
Module	Aluminum	-85	580	76.58
Substrate	Teflon		3,320	5.17
Epoxy	36-2 Epoxy		5,220	-.62

1. Margin of Safety (M) is defined as: $M = \frac{\text{Ultimate Strength}}{\text{Calculated Stress}} - 1$

7.2 Conclusions and Recommendations

7.2.1 Module #1 Dynamics

Due to its high (above 2,500 Hz) resonant frequency, the module (substrate, cover, and module housing) experiences low dynamic stresses (less than 4,000 psi), resulting in margins of safety greater than 10. Therefore, the module is capable of surviving the 24 Grms random vibration, the 3,000g, 3 msec shock, and the 10,000g constant acceleration environments without suffering a structural failure. Since the 10,000g acceleration environment produced the highest dynamic stresses, subsequent analysis concentrated on this environment. Since the module housings are quite stiff, they act like rigid bodies when exposed to dynamic environments. Therefore, future analysis should concentrate on substrates and component leads. When exposed to the 10,000g acceleration environment, the substrate-to-substrate lead also experienced a margin of safety greater than 10. It is therefore capable of surviving the above environments without experiencing a bending failure. However, when the feedthru-to-substrate lead is subjected to the 10,000g acceleration environment, it experiences a negative margin of safety. As it is presently configured, the feedthru-to-substrate lead would suffer a bending failure when exposed to the 10,000g acceleration environment. This conclusion confirms previous test experience of long leads breaking during high acceleration. To alleviate this problem, the feedthru lead's unsupported length should be shortened. This can be done by: (1) locating the feedthru closer to the substrates, and (2) moving the lead's substrate pad closer to the feedthru. Also, bonding the lead to the substrate would improve the lead's structural integrity. When subjected to the measured 40 psi finger spring pressure plus the 10,000g acceleration environment, the substrates and their associated mounting screws experienced margins of safety greater than one. Therefore, the substrates and their mounting screws are capable of surviving the above dynamic environments. It is further recommended that dynamic analysis be done on the large ring-like inductors found on several Module #1 substrates.

7.2.2 Module #1 Connector Thermal Stresses

When the connector's expansion and contraction are not restrained (simulating vendor testing), it experiences positive margins of safety (greater than .10). It can therefore survive the thermal cycling environment in this configuration. When it is installed, expansion and contraction are restrained by the module housing. The connector then experiences negative margins of safety, and some glass cracking may occur. This result confirms previous test experience with glass cracking during thermal cycling. Since glass is a brittle material, cracking will occur when stresses are tensile. This occurs when the connector gets hot (125 ^{o}C). Glass typically fails between 7,000 psi and 14,000 psi. Since the calculated stress is 13,650 psi, failure is a possibility, but not a certainty. It is recommended that a more rigorous analysis be performed. This new analysis would include: (1) using actual connector drawings, as opposed to scaling dimensions from component x-rays, (2) including material thermal fatigue effects, as opposed to using material ultimate strength as a failure criteria, and (3) including nonlinear temperature-dependent material properties, as opposed to using worst-case linear values. It is also recommended that some thermal cycling tests be run on typical connector installations.

7.2.3 Module #1 Feedthru Thermal Stresses

The same conclusions and recommendations that applied to the connector also apply to the feedthru. The following conclusions and recommendations also apply to the feedthru. Epoxy tensile stresses occur when the connector gets cold (-65 ^{o}C). Even though the solder experienced a negative margin of safety (-.56), failure is difficult to assess, since solder thermal stresses above 500 psi tend to relieve themselves! The effects of thermal cycling on solder should be included in a more rigorous analysis. The analysis is conservative since the cushion of solder that surrounds the ceramic was not included. This effect should be included in subsequent analysis.

7.2.4 Module #2 Dynamics

The substrate mounting screws can survive the 40 psi spring pressure plus the 10,000g acceleration without breaking. If the substrate compresses the finger springs to a height of .007 in (simulating actual installation), a bending failure will occur when it is subjected to the 10,000g acceleration environment. The substrate is also not capable of surviving the above environments separately. Several possibilities exist that will help prevent substrate failure. They include: (1) using a different substrate material, possibly 772 alumina, (2) using a thicker substrate, at least .025 in, (3) not using the finger springs, and (4) supporting the substrate in the middle. It is recommended that the substrate's vibratory response, shock response, and dynamic stresses be calculated.

7.2.5 Module #3 Module-to-Cover Joint

Both the epoxied joint and the welded joint can survive the 10,000g acceleration environment. The epoxy joint will crack when exposed to thermal extremes of -65 °C. The epoxy joint does not allow a hermetic seal but was analyzed for comparison purposes.

7.2.6 Module #4 Dynamics

Both the substrate and its mounting screws are capable of surviving the 10,000g acceleration environment.

7.2.7 Module #5 Lead Dynamics

As configured, the feedthru-to-substrate lead will experience a bending failure when subjected to the 10,000g acceleration environment. A lead with .040 in long horizontal and vertical projections (.056 in long) can survive the 10,000g acceleration environment. It is recommended that the lead's substrate pad be moved closer to the feedthru and the feedthru's location be moved closer to the substrate. Bonding the lead to the substrate would also decrease bending stresses in the lead.

7.2.8 Module #5 Substrate Material Comparison

Since dynamic stresses are typically small, all three materials would be suitable for dynamic service. G-10 and teflon are the best dynamic materials whereas teflon and G-10 are the best thermal cycling materials. G-2 is the worst material for both environments. Either G-10 or K-6098 teflon would make suitable substrate materials. The thin solder layer makes model grid optimization difficult. It is recommended that a finer mesh model be used to better assess solder thermal stresses.

7.2.9 Module #6 Thermal Stresses

If epoxy is used to bond the substrate to the module, it will crack at -65 °C. Therefore, epoxy should not be used for this bond. It should be soldered like Module #5. A finer mesh model should also be used to better assess epoxy thermal stresses.

7.3 Method of Analysis

7.3.1 Environments

7.3.1.1 Random Vibration (24 Grms)

The power spectral density spectrum for the random vibration environment is shown in Figure 7.3-1. Vibration was considered to occur in one axis only. The direction of vibration was assumed to be perpendicular to the plane of the module's substrates.

7.3.1.2 Shock (3,000g, 3 msec)

The shock environment consisted of five half-sinc pulses of 3,000g amplitude and 3 msec duration per MIL-STD-883, Method 2002, Condition C. The direction of the shock was that axis which would pull the bonds away from the chips (perpendicular to the plane of the module's substrates and upward).

7.3.1.3 Acceleration (10,000g)

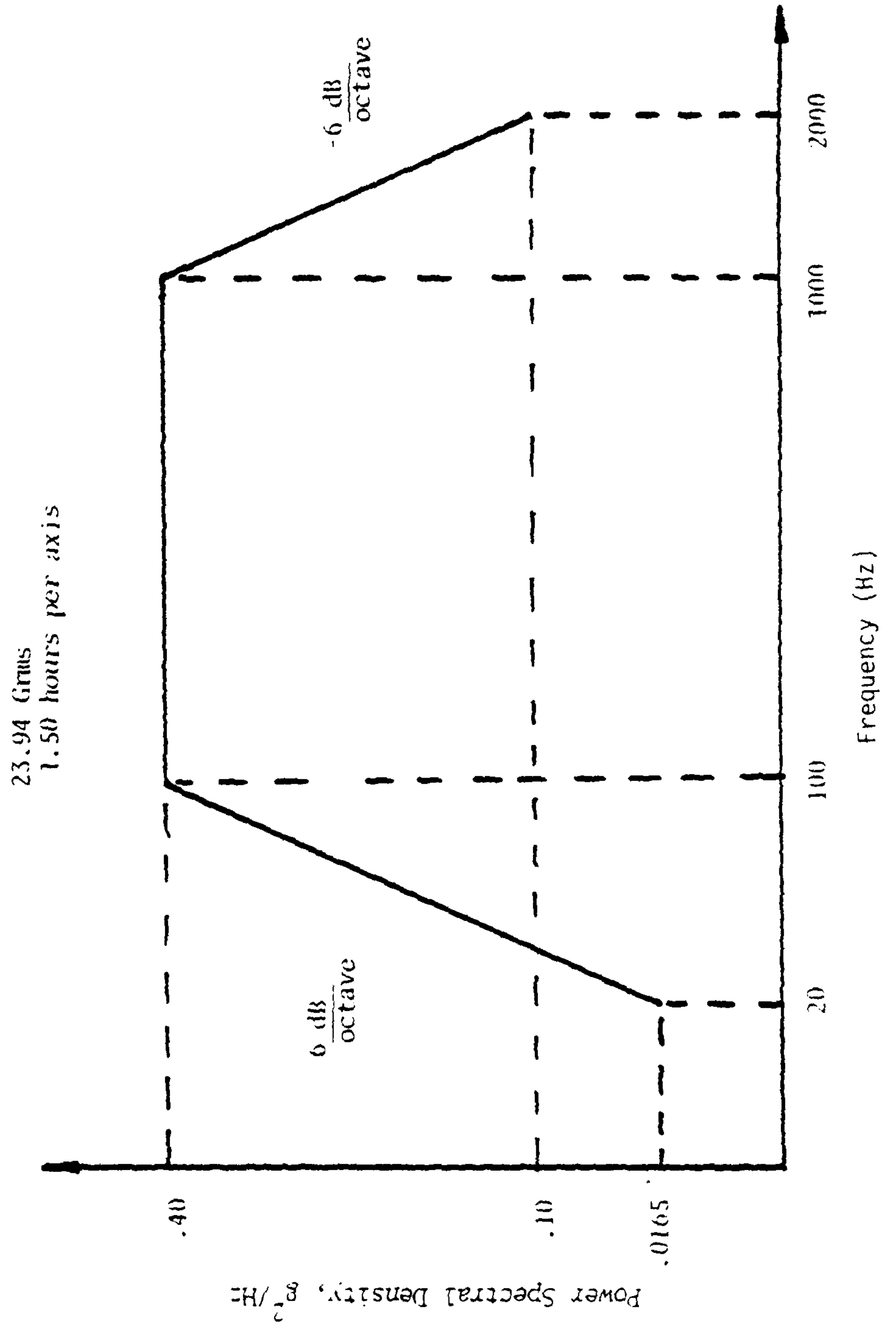
The acceleration environment consisted of one minute of constant 10,000g acceleration per MIL-STD-883, Method 2001, Condition B. The direction of the acceleration was that axis which would pull the bonds away from the chips (perpendicular to the plane of the module's substrates and upward).

7.3.1.4 Thermal Cycling (-65 ^{o}C to 125 ^{o}C)

The thermal cycling environment consisted of 100 thermal cycles per MIL-STD-883, Method 1010, Condition B (Modified). Each thermal cycle consisted of the following steps:

Step	Minutes	Temperature
1	30 minimum	-65° C (-85° F)
2	5 maximum	25° C (77° F)
3	30 minimum	125° C (257° F)
4	5 maximum	25° C (77° F)

Figure 7.3-1. Random Vibration Environment



7.3.2 Module #1 Dynamics

The assembly drawing for Module #1 is shown in Figure 7.3-2. A STARDYNE finite element model was used to determine module dynamic behavior. Cube elements were used to simulate the module housing, and plate elements were used to simulate the cover and the substrates. A three-dimensional view of the model is shown in Figure 7.3-3. Module elements and nodes occurring at various vertical planes are shown in Figures 7.3-4 and 7.3-5. The STARDYNE star dynamic option was utilized to obtain module resonant frequencies and mode shapes. The STARDYNE Dyne 1 program was used to calculate shock response. Finally, the STARDYNE star static option was used to determine dynamic stresses resulting from the shock and acceleration environments.

The module's base was assumed to be bonded - therefore, all base nodes were fully restrained. The module housing is fairly stiff and therefore acts like a rigid body when exposed to dynamic environments. Ten vibratory modes were extracted - all were either cover or substrate plate bending modes. All modes were in the 2,500 Hz to 25,000 Hz frequency range. As shown in Table 7.1-2, dynamic stresses were low (less than 4,000 psi) and margins of safety were high (greater than 10). Since all module housings are relatively stiff, subsequent analysis concentrated on substrates and component leads. As shown in Table 7.1-2, the acceleration environment is worst-case.

A STARDYNE finite element model was used to determine dynamic stresses in the flat substrate-to-substrate lead and the round feedthru-to-substrate lead. Beam elements were used to model the leads. These lead models are shown in Figures 7.3-6 and 7.3-7. In addition to the 10,000g acceleration, loading displacements resulting from the module's acceleration response were applied at the lead's ends. The STARDYNE star static option was then used to calculate lead dynamic stresses.

A STARDYNE finite element model was also made of the substrate. Plate elements were used to represent the substrate. This model is shown in Figure 7.3-8. The STARDYNE star static option was used to compute substrate stresses resulting from the 40 psi finger spring pressure plus the 10,000g acceleration. The 40 psi spring pressure resulted from measurements made when the spring was compressed to a height of .007 in (simulating actual installation). Hand calculations were used to determine screw tensile stresses resulting from the above loading. These hand calculations are shown in the Appendix.

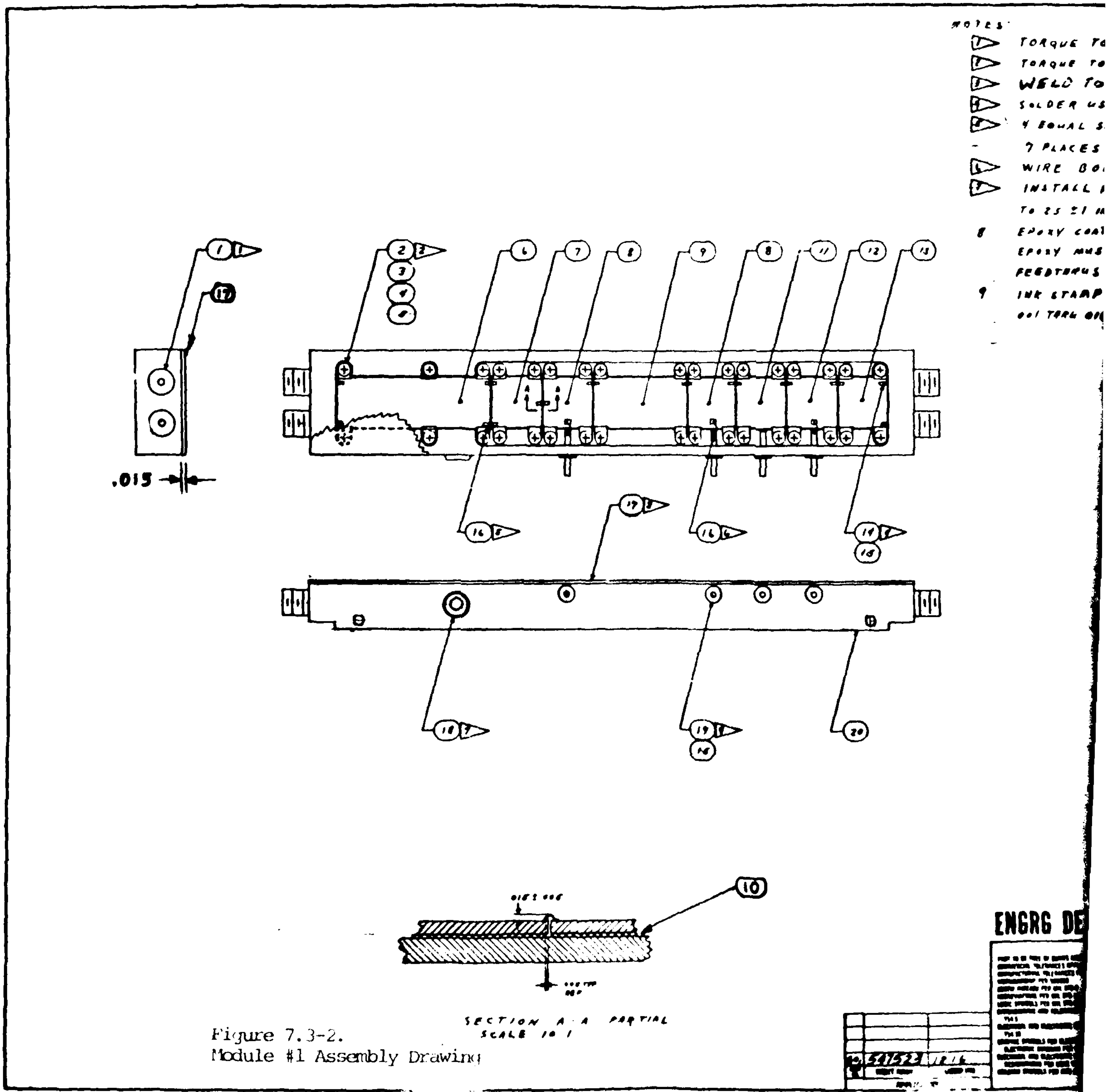
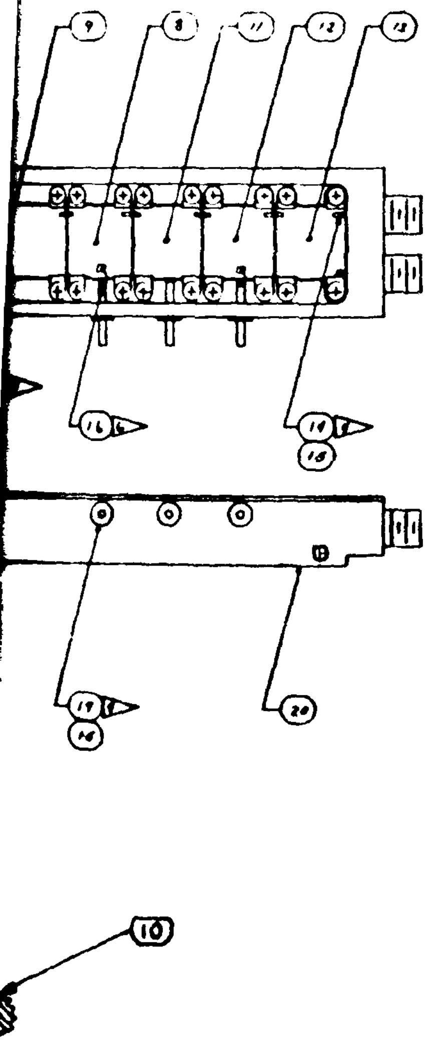


Figure 7.3-2.
Module #1 Assembly Drawing

NOTES:

1. TORQUE TO 25 ± 1 IN LB
2. TORQUE TO 8 ± 1 IN OZ
3. WELD TO ITEM 20.
4. SOLDER USING ITEM 15
5. 4 EQUAL SPACED WIRE BONDS — 7 PLACES
6. WIRE BOND
7. INSTALL FINGER TIGHT, TORQUE TO 25 ± 1 IN LB AT SEALING
8. EPOXY COAT MODULE PER HESD-130407. EPOXY MUST NOT COAT CONNECTORS OR FEEDTHRUS MORE THAN .03 IN FROM MODULE
9. INK STAMP 91417-545767-601 SN 001 THRU 016 PER MIL-STD-130



QTY	ITEM NO	PART OR IDENTIFYING NO	NOMENCLATURE OR DESCRIPTION	CODE IDENT
1	20	545766-001	MODULE	
4	19	4910-502	FEED THRU FILTER	
1	18	605045	SEAL PLUG	
1	17	545766-002	COVER	
AR	16		GOLD WIRE .001 DIA	
AR	15	SN62WRMAP	SOLDER	
4	14	427369	LAUNCH TAP	
1	13	430235 G01	D/C 2 WAY POWER DIVIDER	
1	12	430215 G01	" AMPLIFIER, IFA3	
1	11	430239-G01	INTERCONNECT	
1	10	423651-009	SPRING, FINGER TYPE	
1	9	430221 G01	300/30 MHZ IF BPF	
1	8	430213-G01	IF AMPLIFIER, IFA2	
1	7	430249-G01	C BAND MIXER	
1	6	430243-G01	FILTER, COMMAND CHANNEL	
34	5	309322	CLAMP TAC	
4	4	309321	SPACER	
34	3	MS35338	WASHER, LOCK 0	
34	2		SCREW 0-80 x 3/16	
4	1	705971-001	CONNECTOR	

QUANTITY REQUIRED — LIST OF MATERIALS OR PARTS LIST

ENGRG DEV DWG

MATL: ALUM ALLOY 6061-T6

FINISH: 100 µ Au PLATE

HARRIS — ELECTRONIC SYSTEMS DIVISION, MELBOURNE, FLORIDA

TITLE: DOWN CONVERTER MODULE ASSY

SIZE D | CODE IDENT NO 91417 | 545767

545523 | 1016

Figure 7.3-3. Module #1 Finite Elements

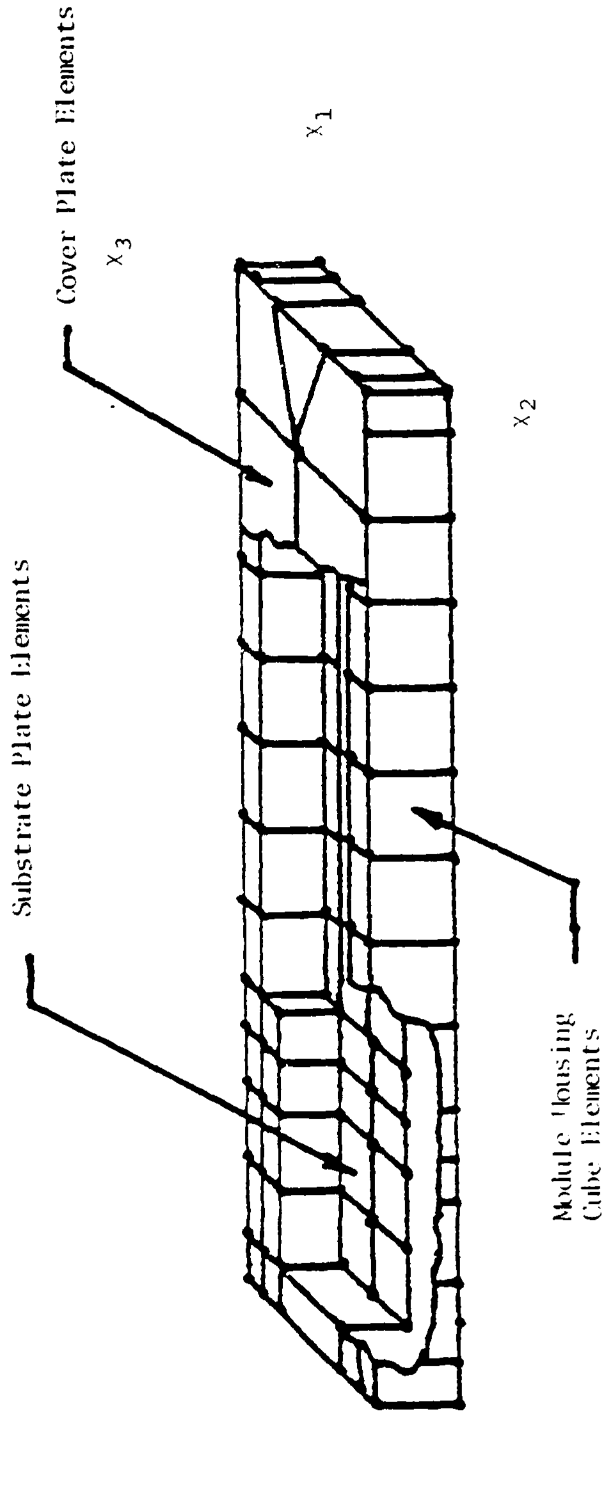


Figure 7.3-4. Module #1 Substrate and Cover Plate Elements

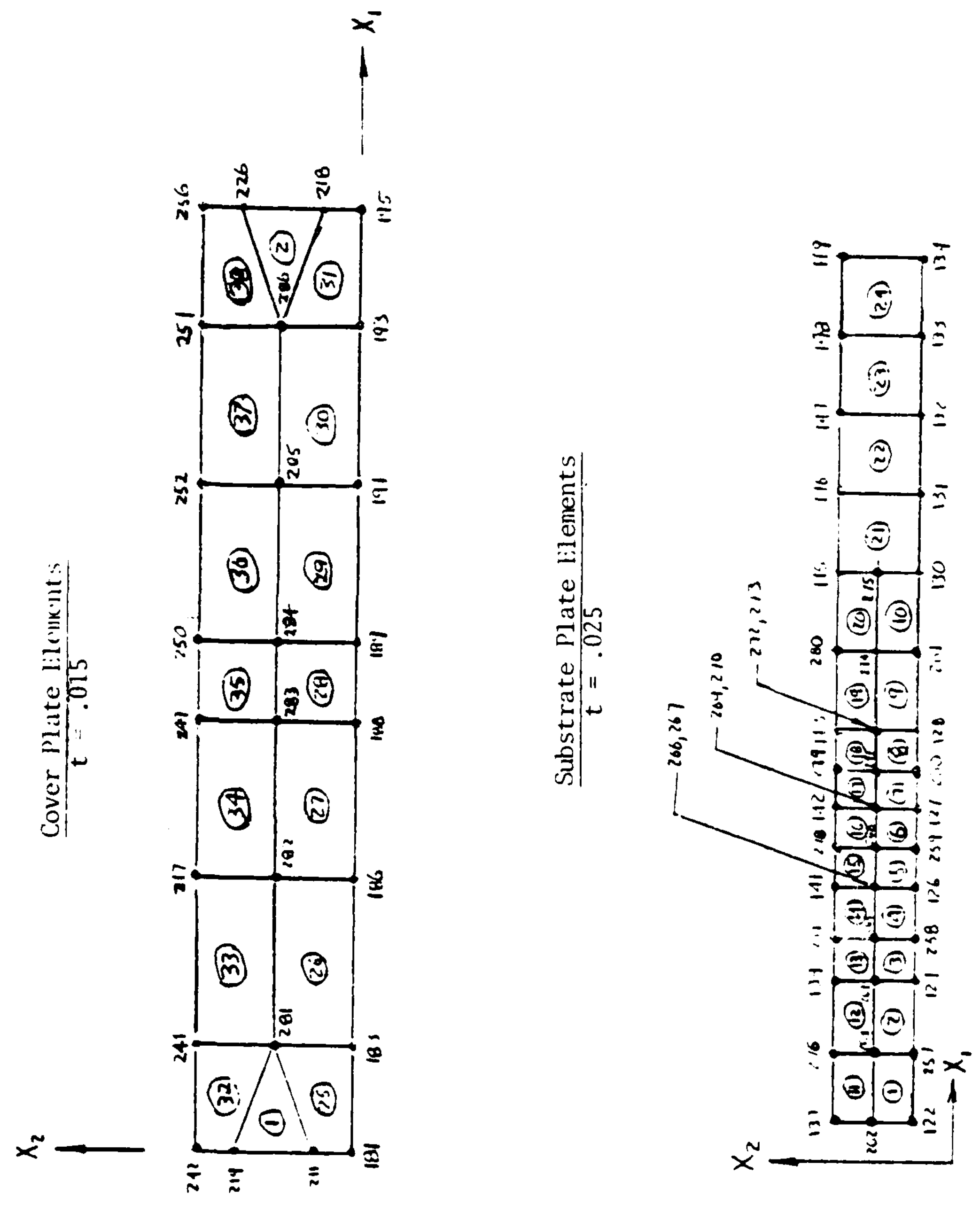


Figure 7.3-5. Module #1 Module Housing Cube Elements

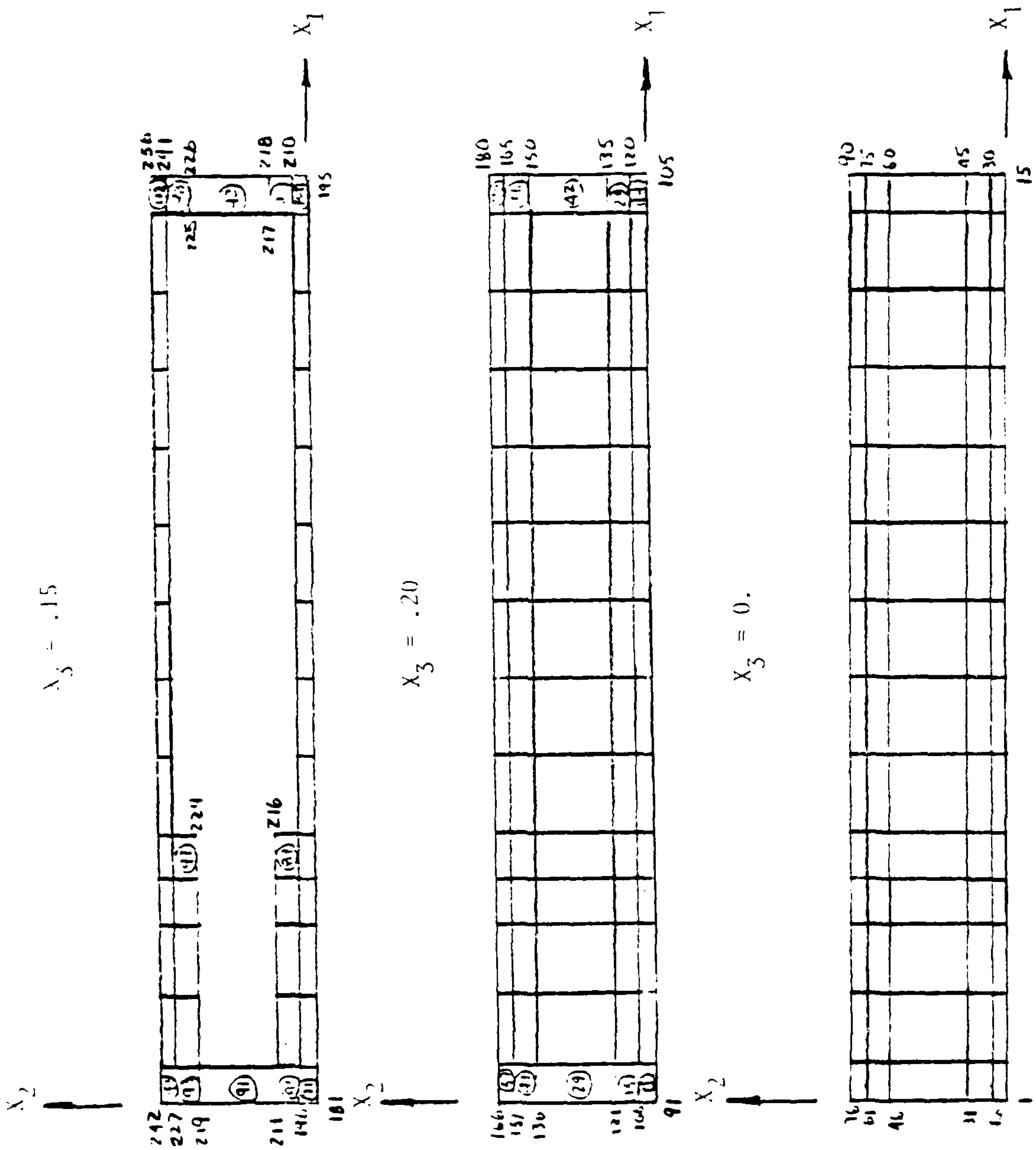


Figure 7.3-6. Module #1 Substrate Lead Finite Element Model

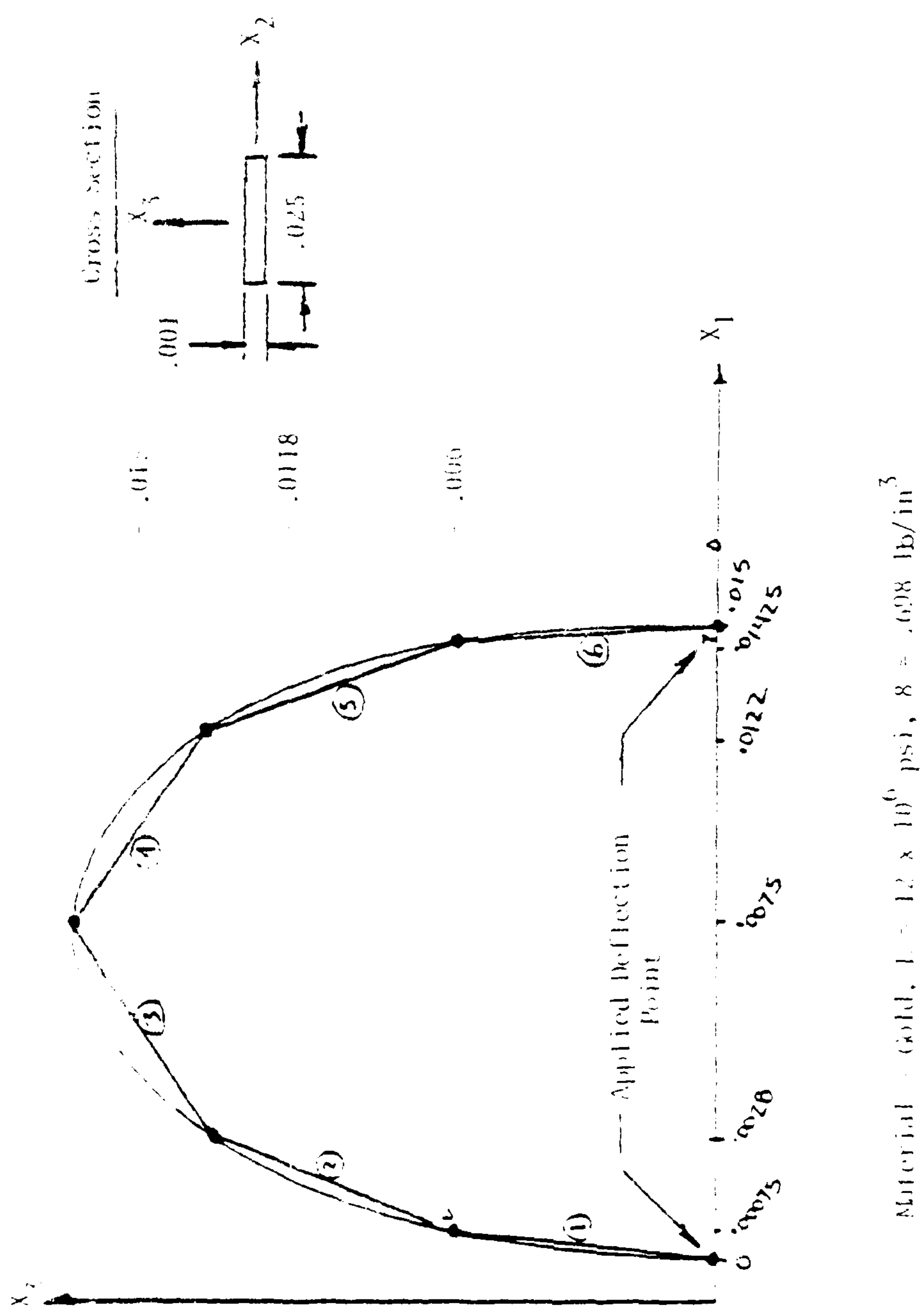
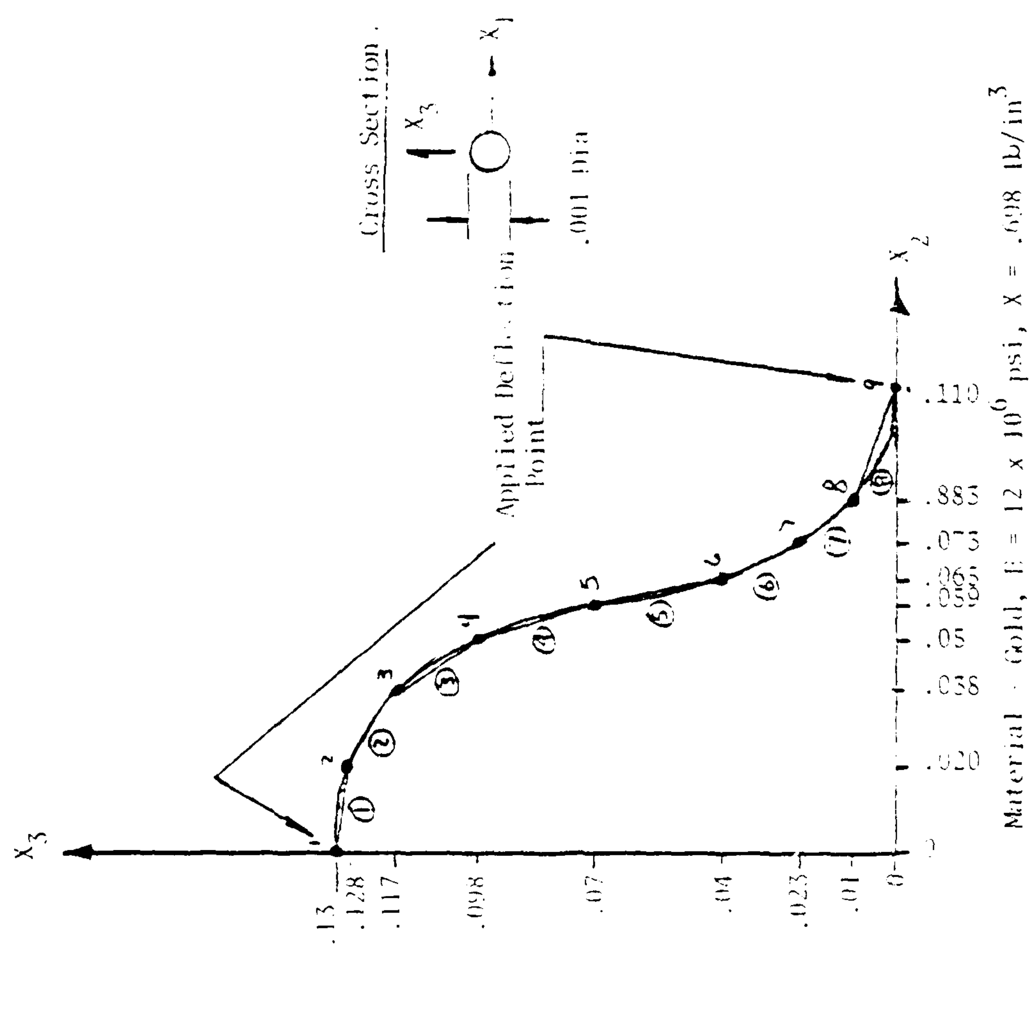


Figure 7.3-7. Module #1 Feedthru Lead Finite Element Model



AD-A090 677 HARRIS CORP MELBOURNE FL GOVERNMENT INFORMATION SYST--ETC F/G 9/5
MICROWAVE INTEGRATED CIRCUITS PROCEDURES EVALUATION.(U)
JUN 80 M F BELGIN, B C MITCHELL, V R BEAHY F30602-78-C-0335

UNCLASSIFIED RADC-TR-80-201 NL

2 OF 3

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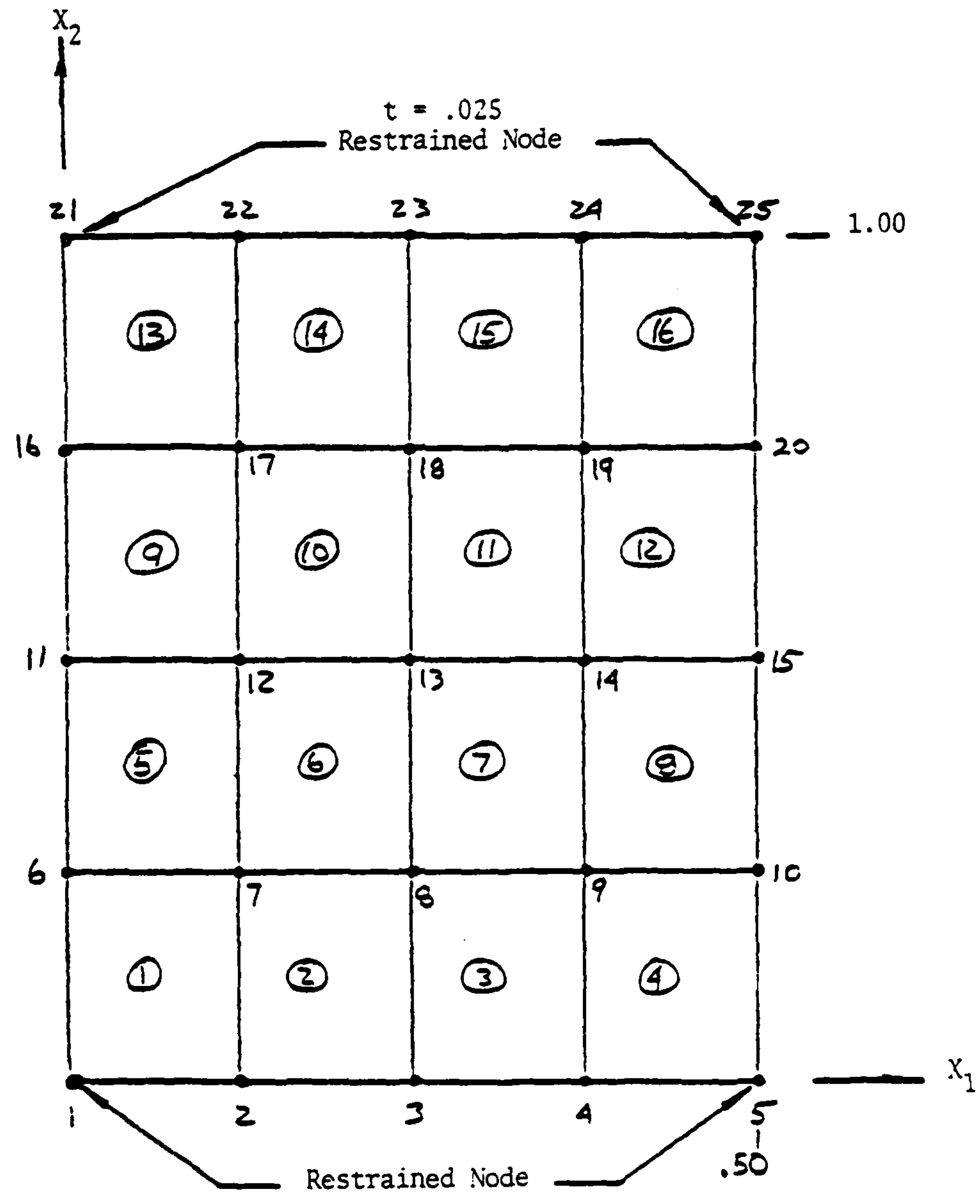
090677

Figure 7.3-8. Module #1 Substrate Finite Element Model



7.3.3 Module #1 Connector Thermal Stresses

The various materials used in the connector are shown in a cross-sectional view in Figure 7.3-9. The ANSYS finite element program was used to determine connector thermal stresses resulting from the thermal cycling environment. An axisymmetric model using the ANSYS STIF42 two dimensional solid element is shown in Figure 7.3-10. The volume of module housing material swept out by the axisymmetric elements is shown in Figure 7.3-11. Two conditions of installation were considered. The first condition was denoted "as installed". Its purpose was to simulate vendor testing where the connector's expansion and contraction were not restrained. It therefore excluded the module housing (elements 50 to 58). A zero stress temperature of 20 ^{o}C was chosen. Stresses were computed based on the temperature differential between the zero stress temperature and either the high or low thermal cycling temperature extremes. Since the connector contains some glass, it was necessary to find which temperature extreme caused tensile glass stresses. This occurred at 125 ^{o}C. Assumptions and limitations of the analysis are discussed in the conclusions and recommendations.

Figure 7.3-9. RF Connector Cross Section

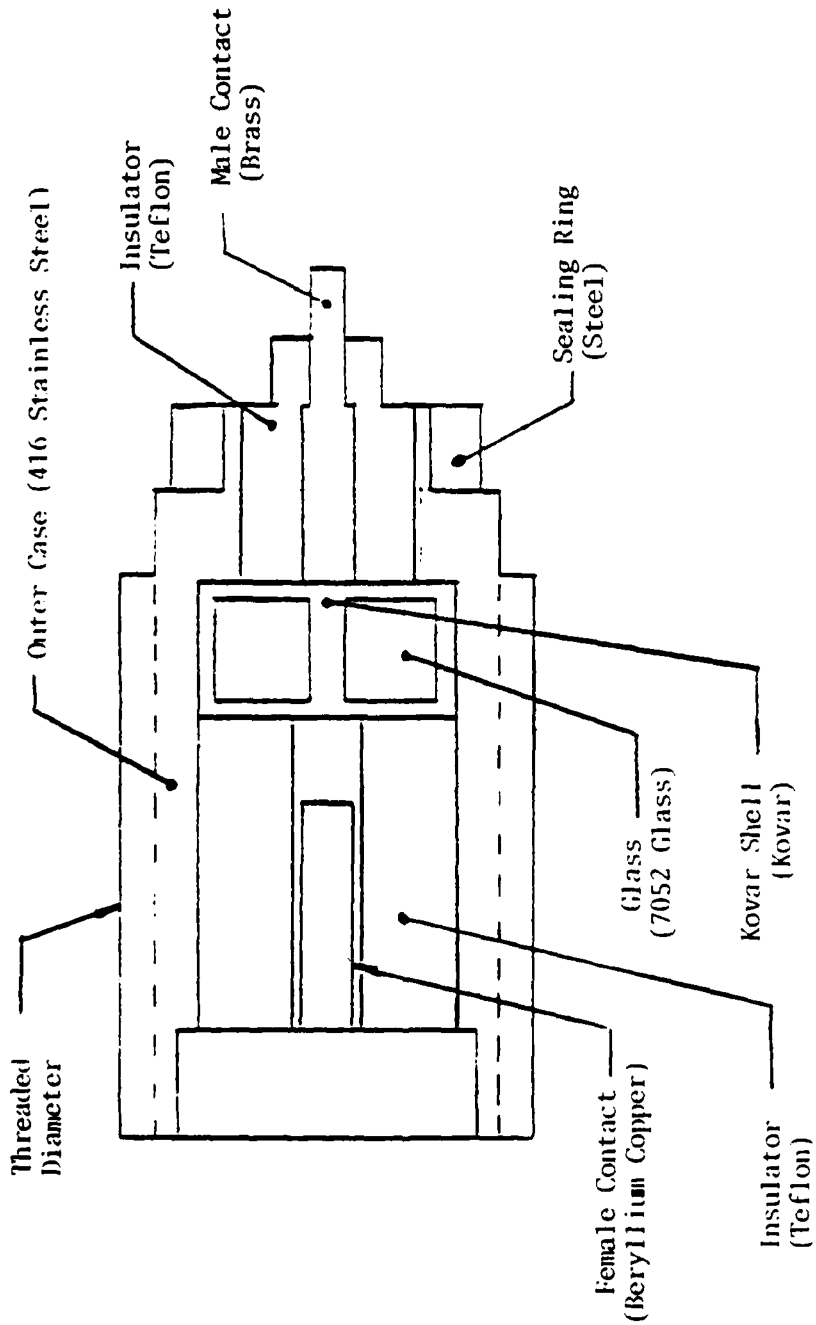


Figure 7.3-10. RF Connector Finite Element Model

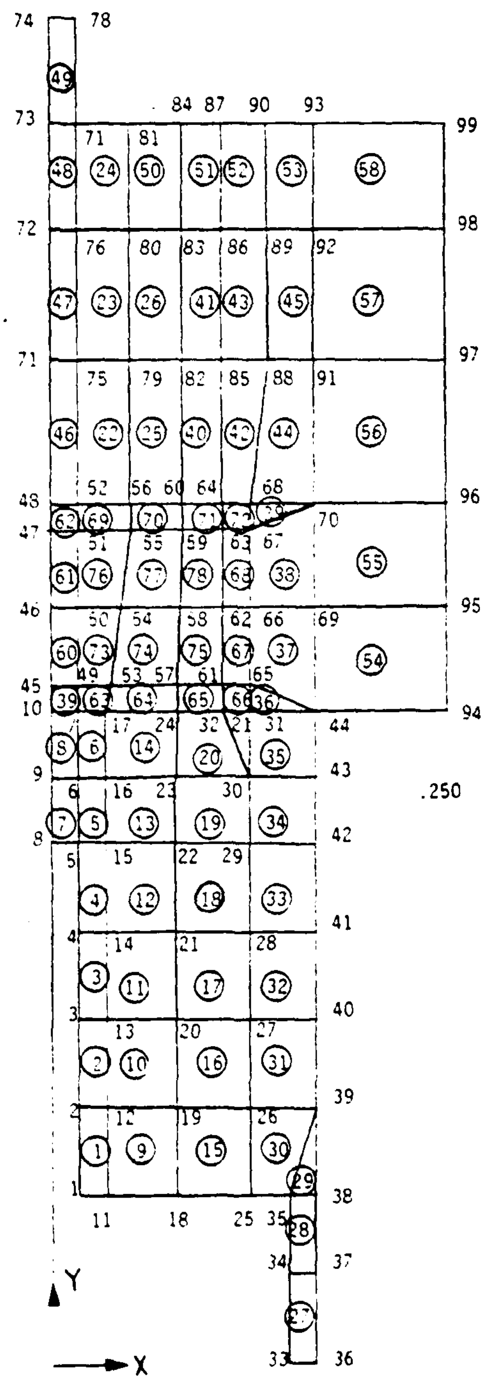
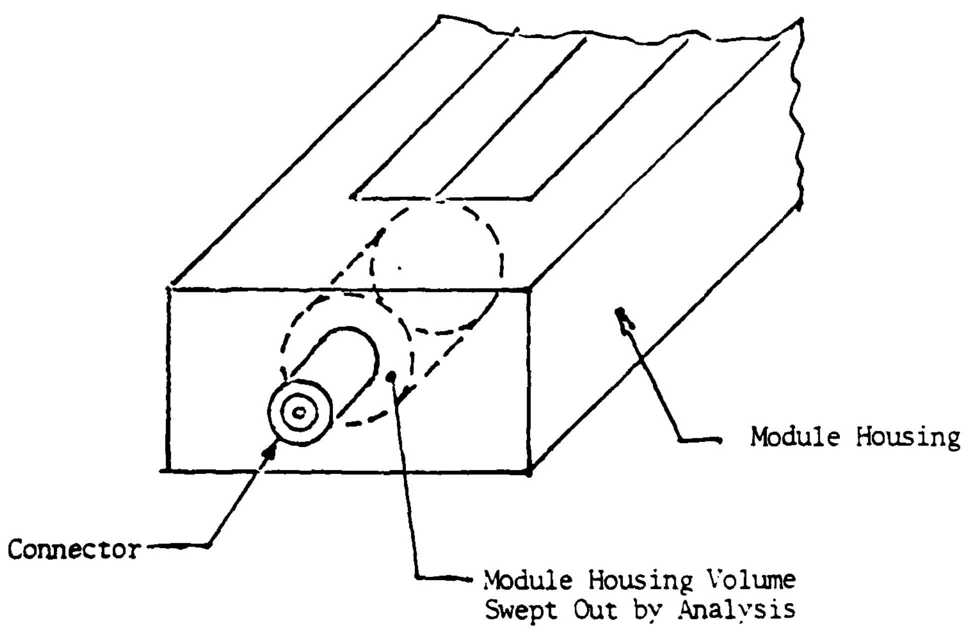


Figure 7.3-11. Module #1 Connector-Module Housing Volume



7.3.4 Module #1 Feedthru Thermal Stresses

The feedthru materials are shown in a cross-sectional view in Figure 7.3-12. The feedthru analysis procedure is basically identical to that of the connector. The axisymmetric finite element model is shown in Figure 7.3-13. The module housing is represented by elements 45 to 54. The volume swept out by these elements is shown in Figure 7.3-14. Glass and ceramic tensile stresses occurred at 125 °C, whereas epoxy tensile stresses occurred at -65 °C assumptions and limitations of the analysis are discussed in the conclusions and recommendations.

Figure 7.3-12. DC Feedthru Cross Section

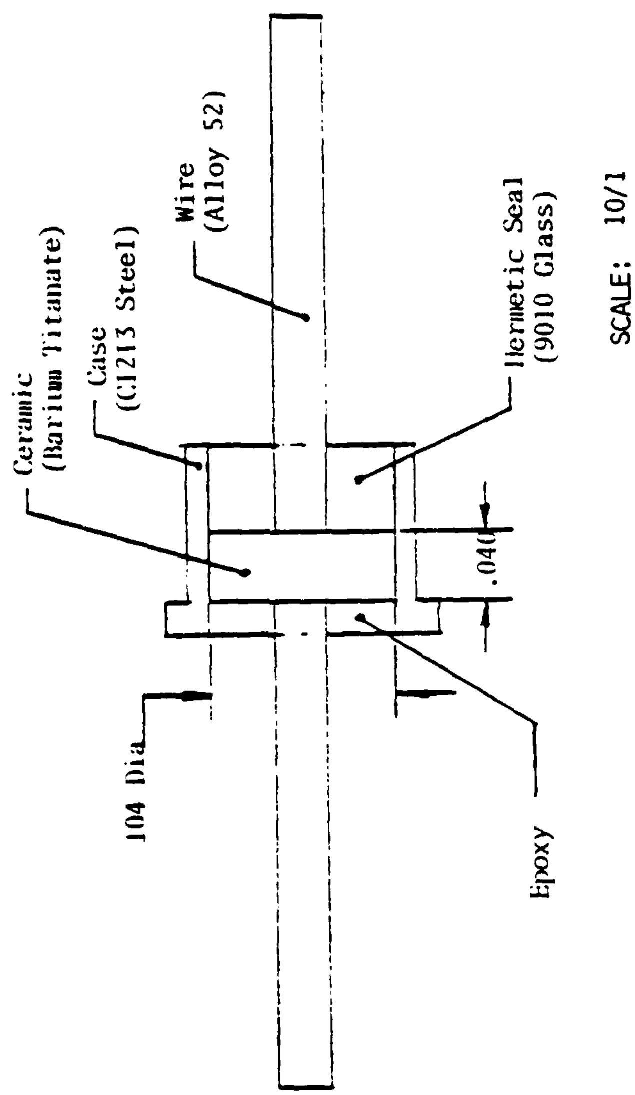


Figure 7.3-13. DC Feedthru Thermal Stress Model

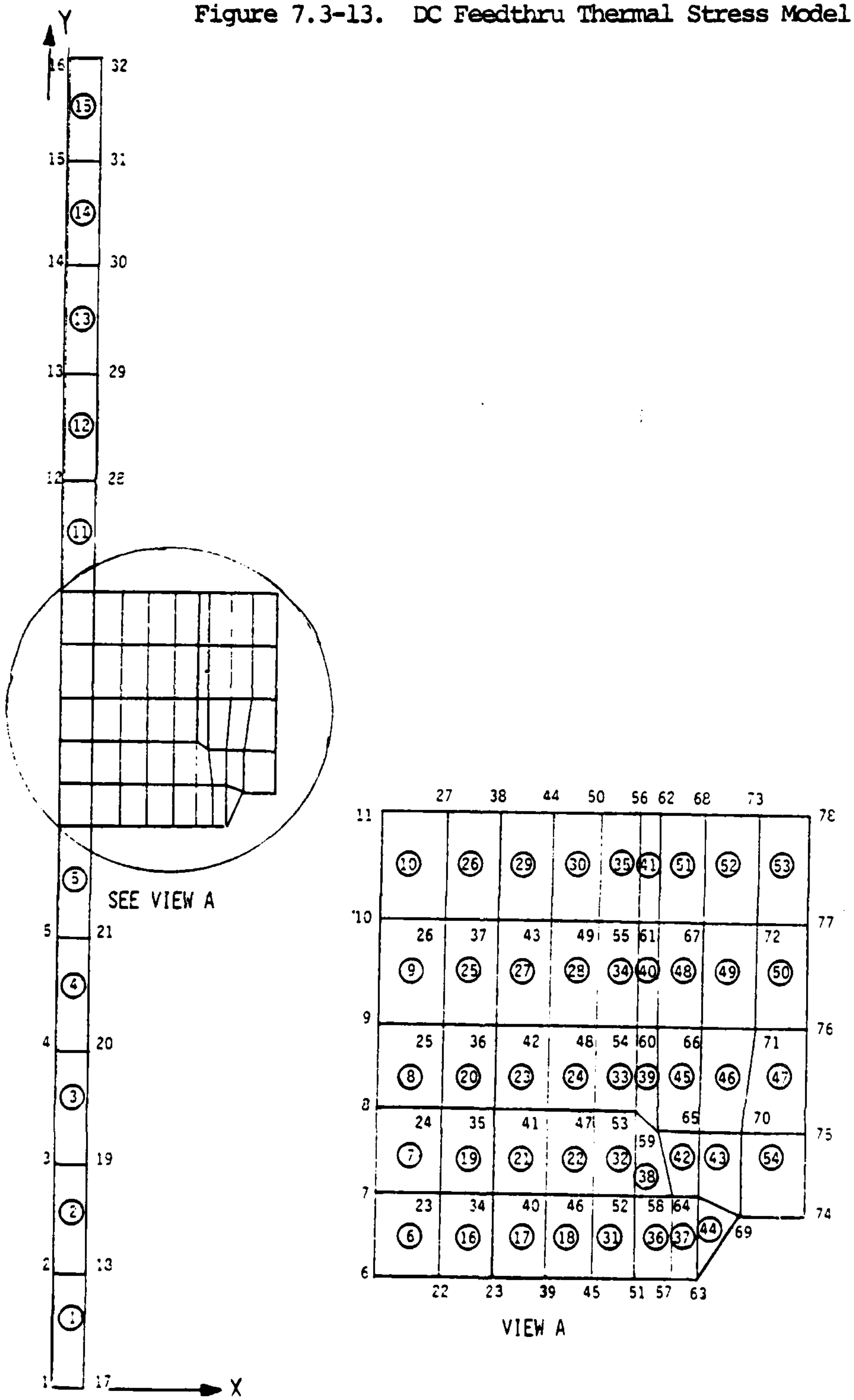
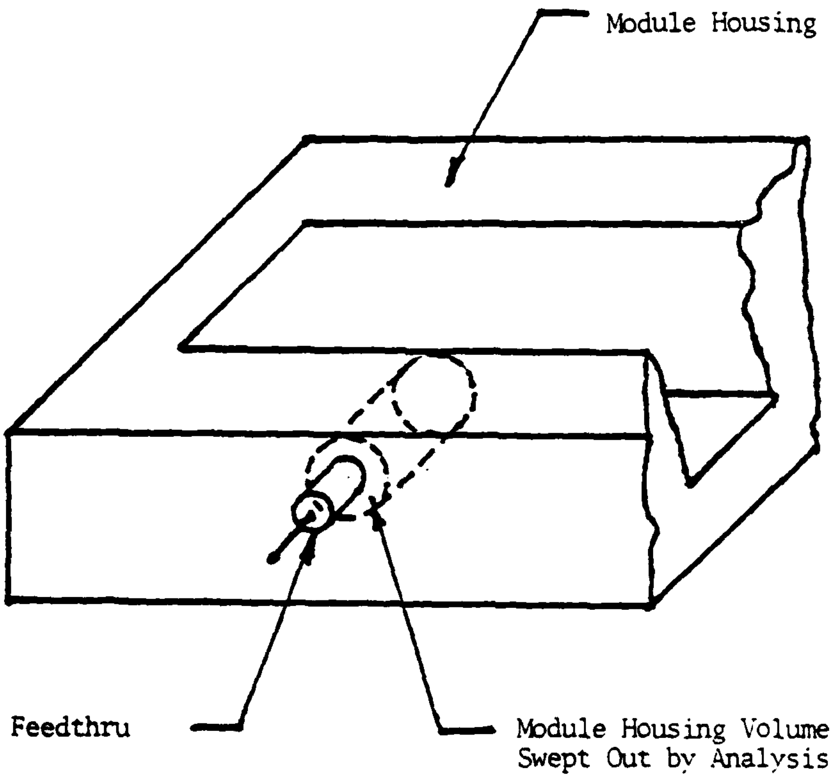


Figure 7.3-14. DC Feedthru Module-Housing Volume



7.3.5 Module #2 Substrate Dynamic Stresses

The module assembly drawing is shown in Figure 7.3-15. A STARDYNE finite element model was used to compute substrate stresses resulting from the 40 psi spring pressure plus the 10,000g acceleration. Plate elements were used to represent the substrate. The finite element model is shown in Figure 7.3-16. Hand calculations were used to compute substrate mounting screw tensile stresses resulting from the above environment. These hand calculations are shown in the Appendix.

7.3.6 Module #3 Cover Joint Dynamic and Thermal Stresses

The assembly drawing of the module is shown in Figure 7.3-17. Dynamic and thermal stresses were computed to determine the effectiveness of welded or epoxied cover-to-module joints. Hand calculations were made to determine dynamic stresses resulting from the 10,000g acceleration environment. These hand calculations are shown in the Appendix. An ANSYS axisymmetric finite element model was made to determine thermal stresses. This model is shown in Figure 7.3-18. The volume swept out by this model is shown in Figure 7.3-19. Epoxy tensile stresses occurred at -65 ^{o}C. An epoxy thickness of .003 in was assumed.

7.3.7 Module #4 Substrate Dynamic Stresses

The assembly drawing of the module is shown in Figure 7.3-20. A STARDYNE finite element model was made of the substrate to determine dynamic stresses resulting from the 10,000g acceleration environment. This model is shown in Figure 7.3-21. Plate elements were used to represent the substrate. Hand calculations were used to compute mounting screw tensile stresses resulting from the above environment. These calculations are shown in the Appendix.

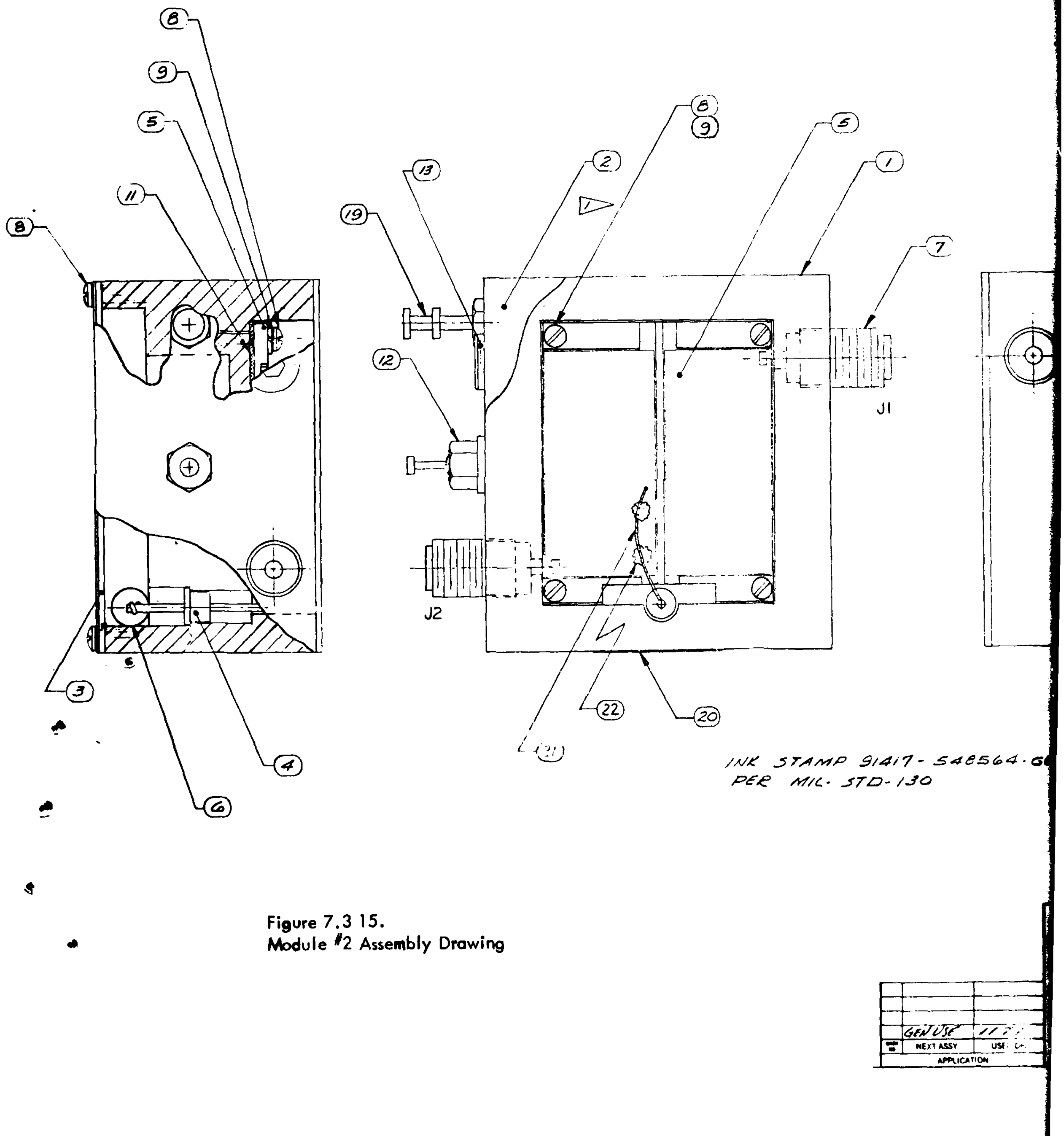
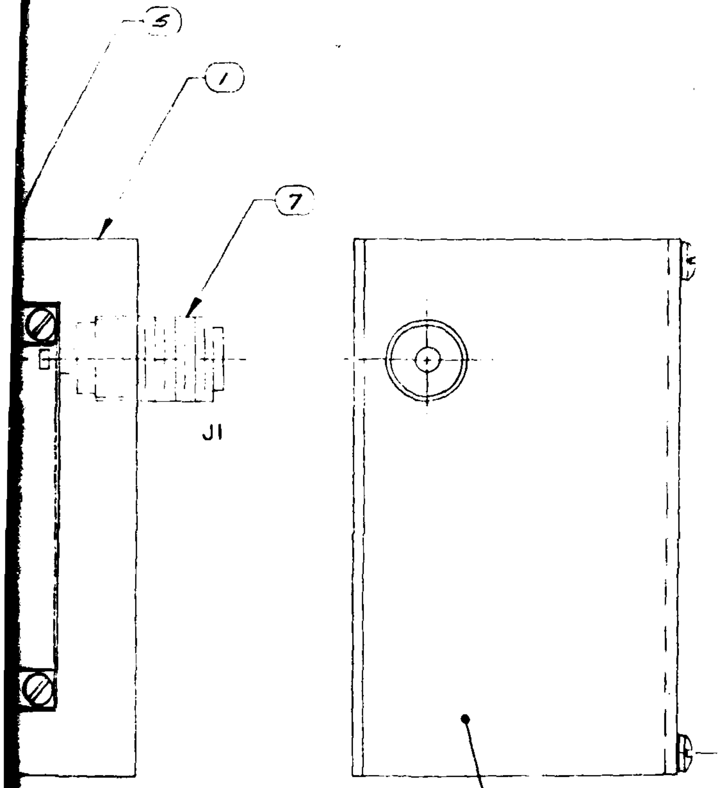


Figure 7.3 15.
Module #2 Assembly Drawing

REVISIONS				
ZONE	LTR	DESCRIPTION	DATE	APPROVED
	A	ADDED ITEMS 21 & 22		

NOTES:

1. WELD ITEM NO. 2 TO ITEM NO. 1.
2. SOLDER PER MIL-STD-454 REQTS.
3. SELECT AT TEST AND BOND IN PLACE USING ITEM 14.
4. REF. TEST SPECIFICATION SEE HESD 10730.



STAMP 91417-548564-001 PER MIL-STD-130

QTY REQD 601	ITEM NO	PART OR IDENTIFYING NO	NOMENCLATURE OR DESCRIPTION	CODE IDENT
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AR	21	.001 DIA	AU BONDING WIRE	
1	20	850119	NAMEPLATE	
1	19	2051-1	GROUND STUD # 4-40	06540
AR	18	SN62WRMAP3	SOLDER PASTE	
2	17	427369-001	LAUNCH TAB	
2	16	543658-001	INTERCONNECT RIBBON	
AR	15	3M-280	EPOXY	
AR	14	36-2	EPOXY, COND.	
1	13	605045	SEAL PLUG	
1	12	3313-000	EMI/RFI FILTER .10 MFD	16546
AR	11	423651-001	SPRING FINGER TYPE	
4	10	312542-001	SPACER	
4	9	CLW 10	WASHER, SPLIT #0	
8	8	501200	SCR, MACH #0-80 x 3/16	
2	7	PDM 971	CONNECTOR	09040
3 ▷ 1	6	RCR07-SAT	RESISTOR, FXD FILM MIL-R-39008 R	
1	5	431977-601	ULNA	
2	4	9900	FEED-THRU/FILTER	16546
1	3	432051-001	COVER, BOTTOM	
1	2	432051-002	COVER, TOP, .015 THICK	
1	1	548563-001	MODULE	

QUANTITY REQUIRED — LIST OF MATERIALS OR PARTS LIST

NEXT ASSY	USED ON
GEN USE	

APPLICATION

PART TO BE FREE OF BURRS AND SHARP EDGES
COMMERCIAL TOLERANCES APPLY TO STOCK SIZES
MANUFACTURING TOLERANCES PER 900002
WORKMANSHIP PER 900060
SCREW THREADS PER MIL STD 9
ABBREVIATIONS PER MIL STD 12
LOGIC SYMBOLS PER MIL STD 806
DIMENSIONING AND TOLERANCING PER USAS Y14.5
ELECTRICAL AND ELECTRONIC DIAGRAM PER USAS Y14.15
GRAPHIC SYMBOLS FOR ELECTRICAL AND ELECTRONIC DIAGRAM PER USAS Y32.2
ELECTRICAL AND ELECTRONIC REFERENCE DESIGNATIONS PER USAS Y32.16
SYMBOLS PER AWS A2.0

UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES AND INCLUDE APPLIED FINISH
TOLERANCES
2 PLACE DIM ± 3 PLACE DIM ± ANGLES ±

MATL: ALUM. ALLOY 6061-T6

FNSH: 50µi Au PLATE

DRAWN: 2 APR 77 DON WHITE

23 JAN 78

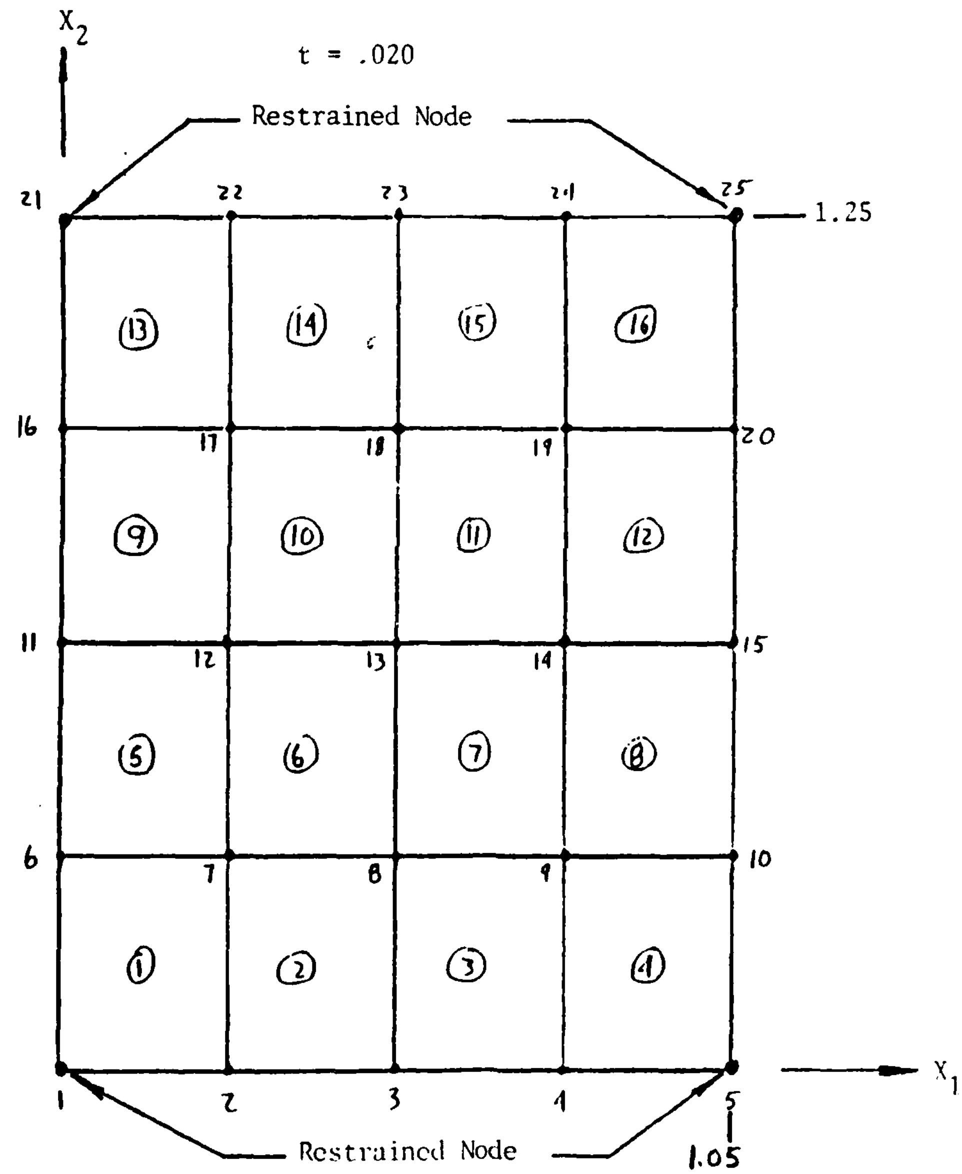
HARRIS ELECTRONIC SYSTEMS DIVISION MELBOURNE FLORIDA 32901

TITLE: AMPLIFIER MODULE ASSY (ULTRA LOW NOISE)

SIZE	CODE IDENT NO		REV
D	91417	548564	A

SCALE 4/1 SHEET

Figure 7.3-16. Module #2 Substrate Finite Element Model



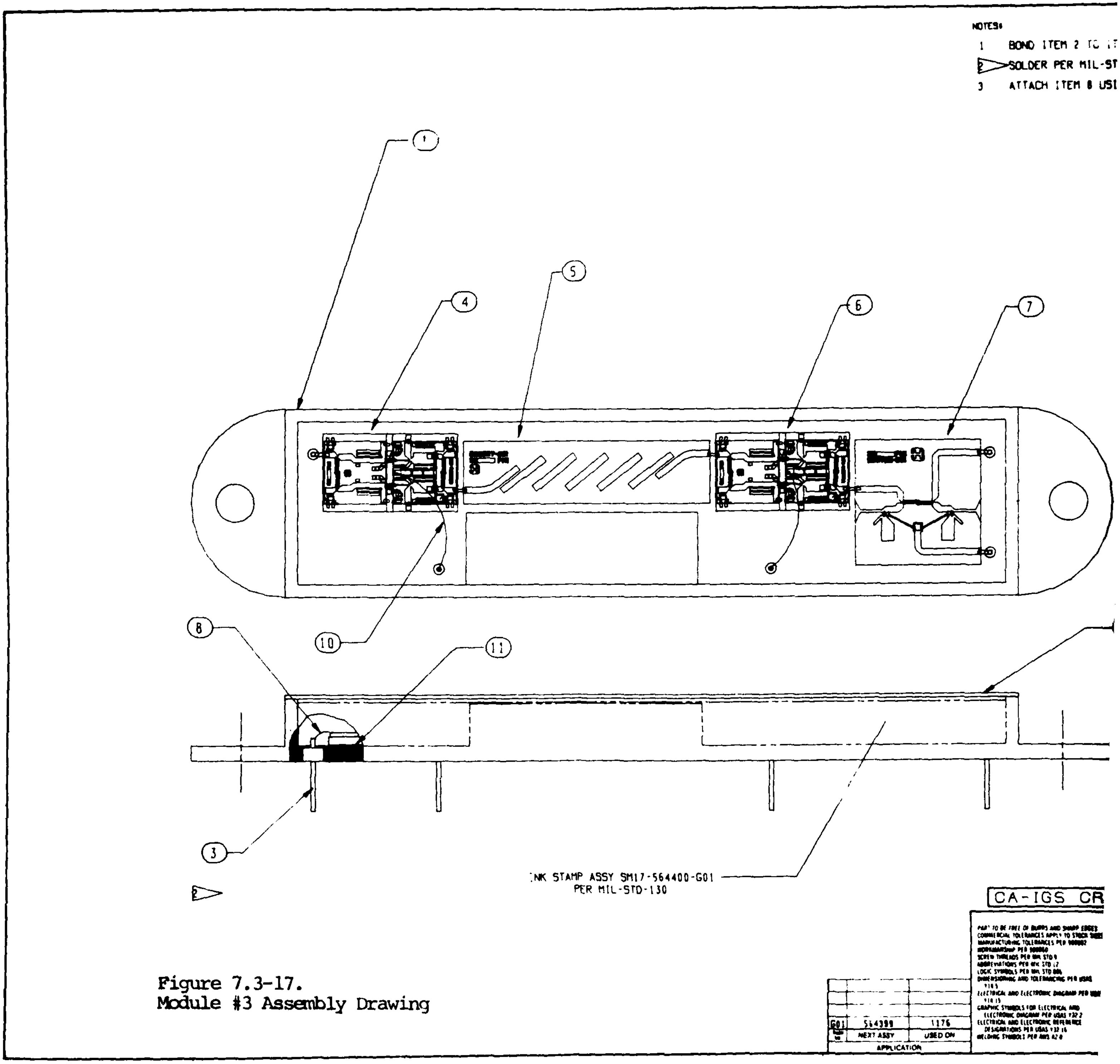


Figure 7.3-17.
Module #3 Assembly Drawing

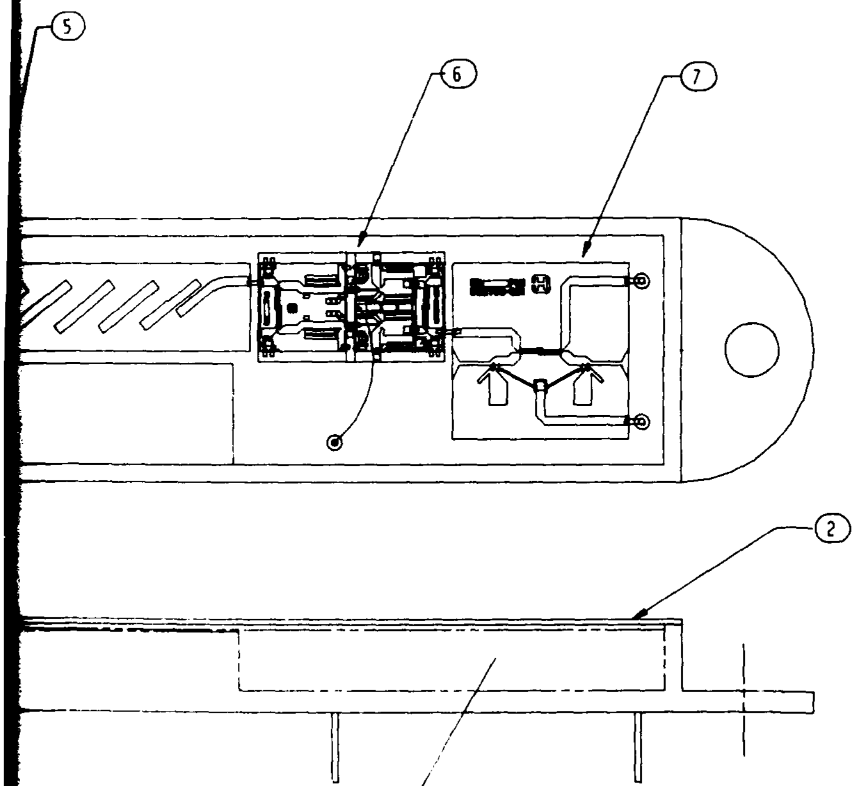
REVISIONS				
ZONE	LTR	DESCRIPTION	DATE	APPROVED

NOTES:

1 BOND ITEM 2 TO ITEM 1 USING ITEM 11

2 SOLDER PER MIL-STD-454 REQT 5

3 ATTACH ITEM 8 USING ITEM 11



STAMP ASSY SM17-564400-G01
PER MIL-STD-130

SEE SEPARATE PARTS LIST PL564400

CA-IGS CREATED

	ITEM NO	PART OR IDENTIFYING NO	NOMENCLATURE OR DESCRIPTION	CODE IDENT
QUANTITY REQUIRED	LIST OF MATERIALS OR PARTS LIST			

G01	564399	1176
	NEXT ASSY	USED ON
APPLICATION		

PART TO BE FREE OF BURRS AND SHARP EDGES
COMMERCIAL TOLERANCES APPLY TO STOCK SIZES
MANUFACTURING TOLERANCES PER 900002
WORKMANSHIP PER 900060
SCREW THREADS PER MIL STD 9
ABBREVIATIONS PER MIL STD 12
LOGIC SYMBOLS PER MIL STD 806
DIMENSIONING AND TOLERANCING PER USAS Y14 5
ELECTRICAL AND ELECTRONIC DIAGRAM PER USAS Y14 15
GRAPHIC SYMBOLS FOR ELECTRICAL AND ELECTRONIC DIAGRAM PER USAS Y32 2
ELECTRICAL AND ELECTRONIC REFERENCE DESIGNATIONS PER USAS Y32 16
WELDING SYMBOLS PER AWS A2 0

UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES AND INCLUDE APPLIED FINISH TOLERANCES
2 PLACE DIM ± 3 PLACE DIM ± ANGLES ±

HARRIS ELECTRONIC SYSTEMS DIVISION MELBOURNE FLORIDA 32901

TITLE RF DOWNCONVERTER MODULE ASSEMBLY

SIZE	CODE IDENT NO		REV
D	91417	564400	
SCALE 5:1	SHEET		

Figure 7.3-18. Module #3 Joint Finite Element Model

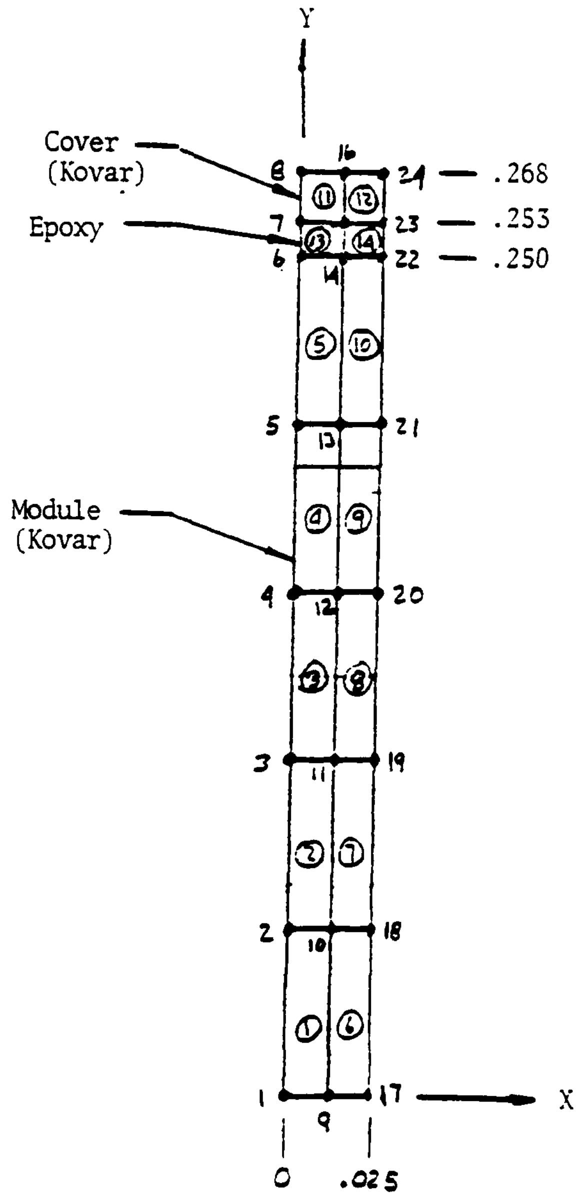


Figure 7.3-19. Module #3 Module Housing Volume

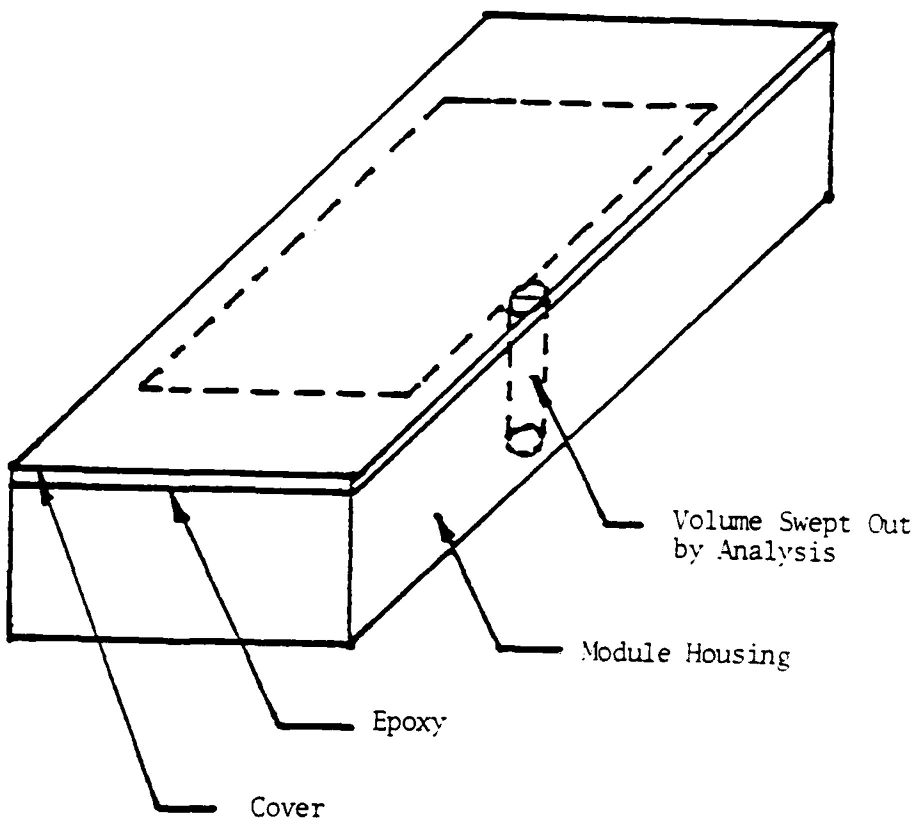


Figure 7.3-20.
Module #4 Assembly Drawing

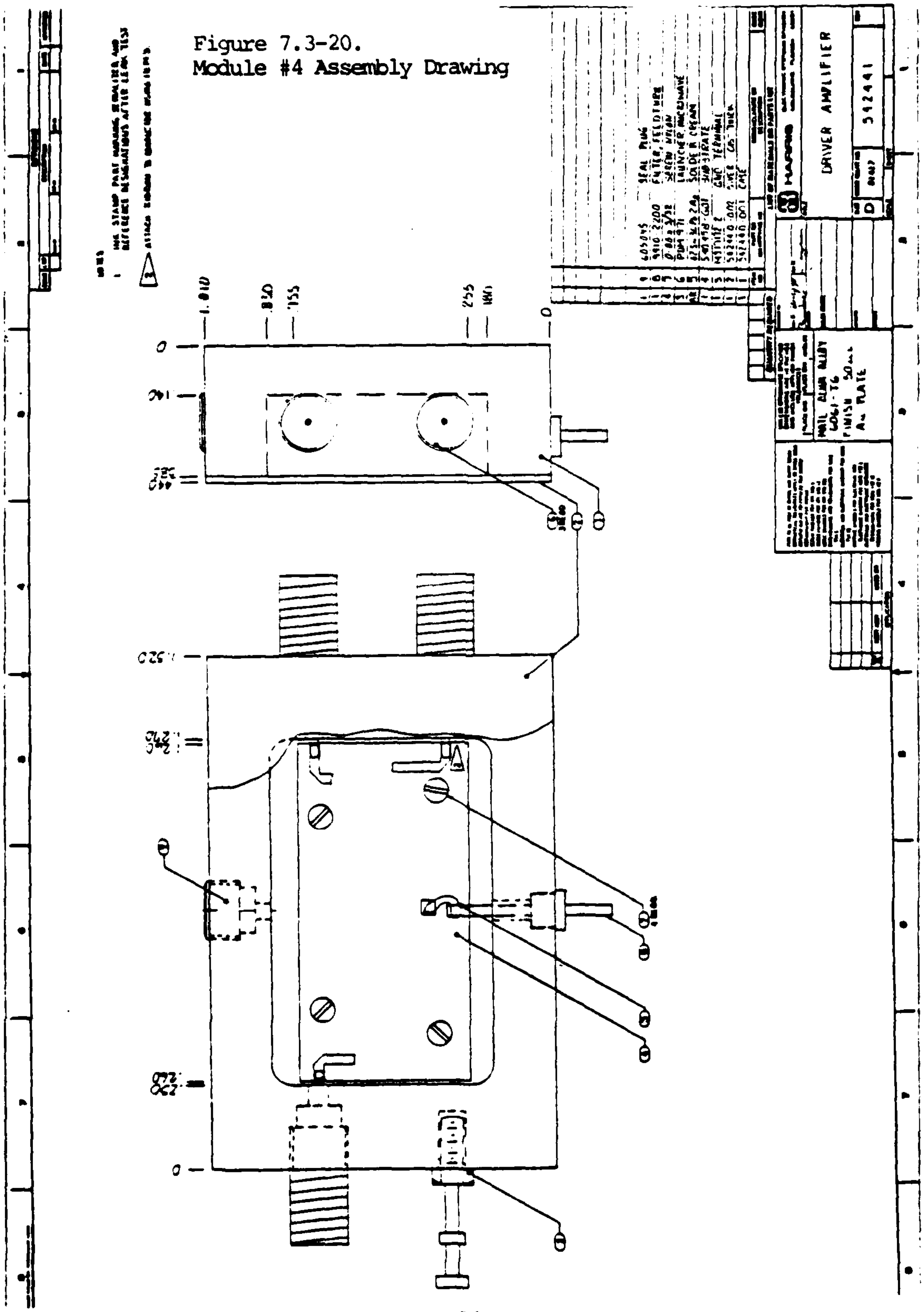
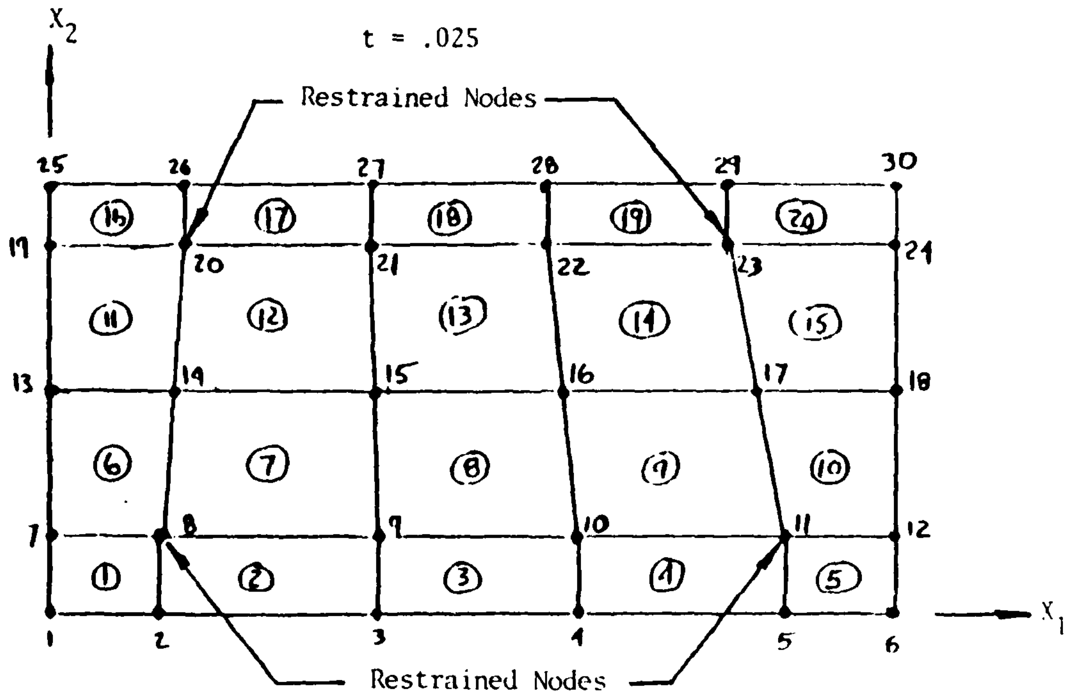


Figure 7.3-21. Module #4 Substrate Finite Element Model



7.3.8 Module #5 Lead Dynamic Stresses

The module assembly drawing is shown in Figure 7.3-22. A STARDYNE finite element model was made of the feedthru-to-substrate lead to determine dynamic stresses resulting from the 10,000g acceleration environment. This model is shown in Figure 7.3-23. It should be noted that beam elements were used to represent the lead, even though the lead's cross-sectional dimensions dictate the use of plate elements. This was done to assure fixity at the lead's ends. Plate elements allow rotation between end nodes, thus negating the fixity effect. Since the initial lead configuration resulted in high stresses (706,600 psi), three other configurations were analyzed. The Optimum configuration consists of a lead with .040 in horizontal and vertical projections (.056 in long).

7.3.9 Module #5 Substrate Materials Comparison

Three substrate materials (G-10, fiberglass (602), and K-6098 Teflon) were evaluated by determining their ability to survive the dynamic and thermal stress environments. A fourth material, duroid, was not evaluated because material properties were not obtained. Two parameters were used to evaluate each material's ability to survive the dynamic environments: (1) stiffness-to-weight ratio (ratio of Young's Modules to weight density), and (2) ultimate strength. The material rankings based on dynamic environment are shown in Table 7.1-7. An ANSYS axisymmetric finite element model was made to calculate thermal stresses for each material. This model is shown in Figure 7.3-24. The volume swept out by this model is shown in Figure 7.3-25. The material rankings based on thermal stresses are shown in Table 7.1-8. A solder thickness of .003 in was assumed.

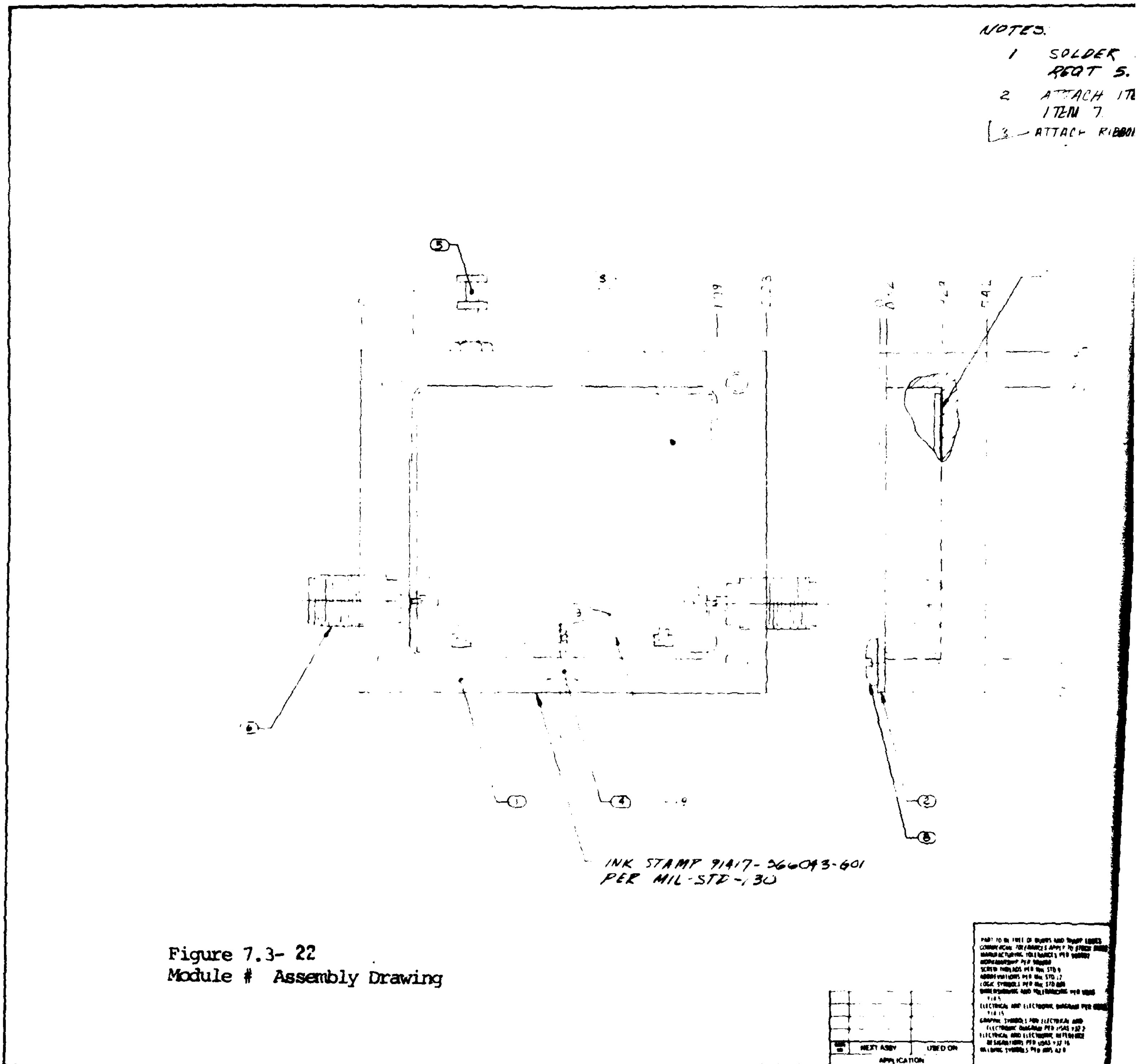


Figure 7.3- 22
Module # Assembly Drawing

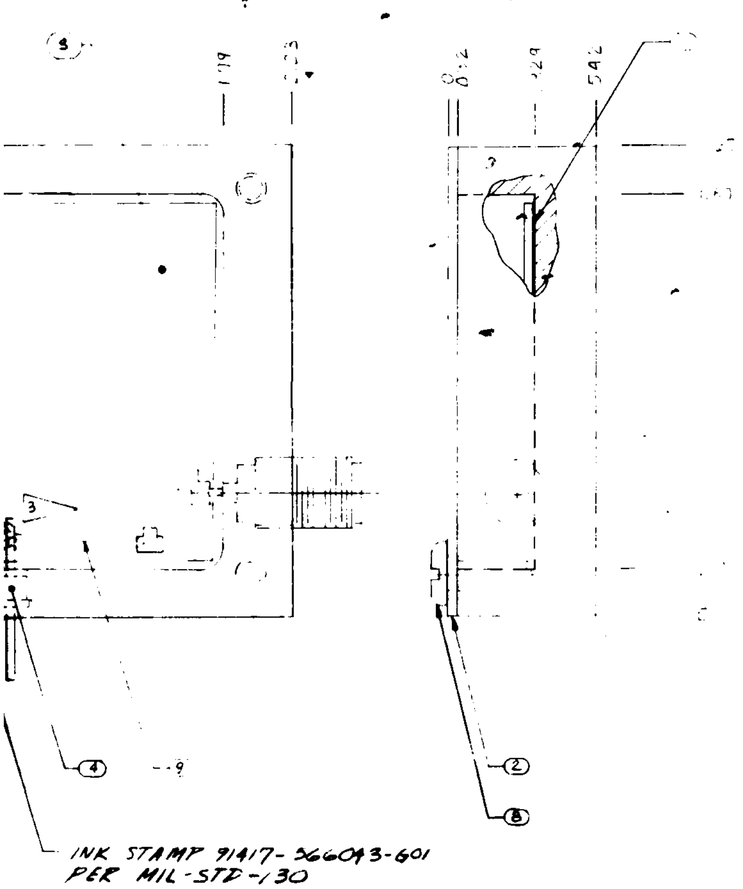
REVISIONS				
ZONE	LTR	DESCRIPTION	DATE	APPROVED

NOTES.

1 SOLDER PER MIL-STD-454 REQT 5.

2 ATTACH ITEM 4 TO ITEM 2 USING ITEM 7.

3 ATTACH RIBBONS (ITEM 9) USING ITEM 7.



ITEM NO	PART OR IDENTIFYING NO	NOMENCLATURE OR DESCRIPTION	CODE IDENT

QUANTITY REQUIRED — LIST OF MATERIALS OR PARTS LIST

PART TO BE FREE OF BURRS AND SHARP EDGES
COMMERCIAL TOLERANCES APPLY TO STOCK SIZES
MANUFACTURING TOLERANCES PER 900007
WORKMANSHIP PER 900006
SCREW THREADS PER MIL STD 9
ABBREVIATIONS PER MIL STD 12
LOGIC SYMBOLS PER MIL STD 806
DIMENSIONING AND TOLERANCING PER USAS Y14.5
ELECTRICAL AND ELECTRONIC DIAGRAM PER USAS Y14.15
GRAPHIC SYMBOLS FOR ELECTRICAL AND ELECTRONIC DIAGRAM PER USAS Y32.2
ELECTRICAL AND ELECTRONIC REFERENCE DESIGNATIONS PER USAS Y32.16
WELDING SYMBOLS PER AWS A2.0

UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES AND INCLUDE APPLIED FINISH TOLERANCES
2 PLACE DIM 3 PLACE DIM ANGLES

MATL ALUM ALLOY 6061-T6

FINISH ... Au PLATE

NEXT ASSY	USED ON
APPLICATION	

HARRIS ELECTRONIC SYSTEMS DIVISION MELBOURNE FLORIDA 32901

TITLE

SIZE	CODE IDENT NO		REV
D	91417		

SCALE SHEET

Figure 7.3-23. Module #5 Lead Finite Element Model

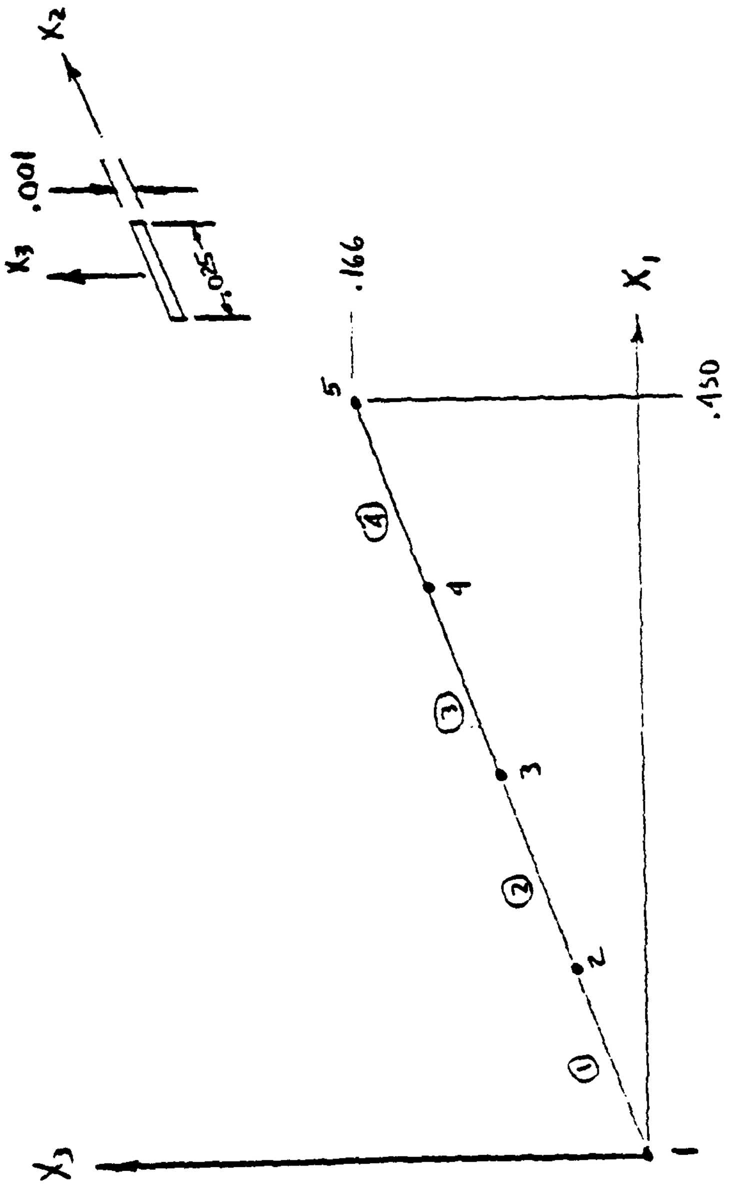


Figure 7.3-24. Module #5 Substrate Joint Finite Element Model

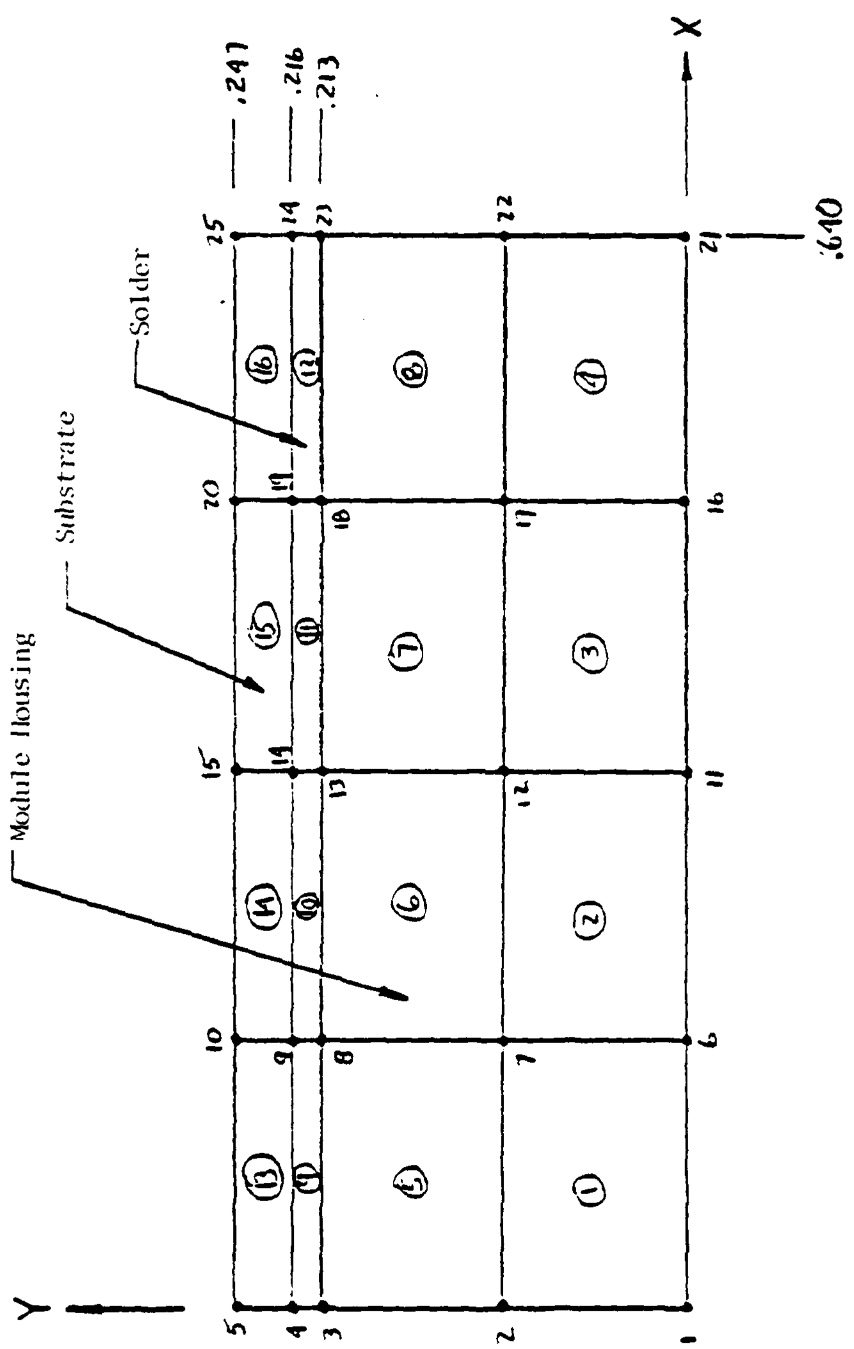
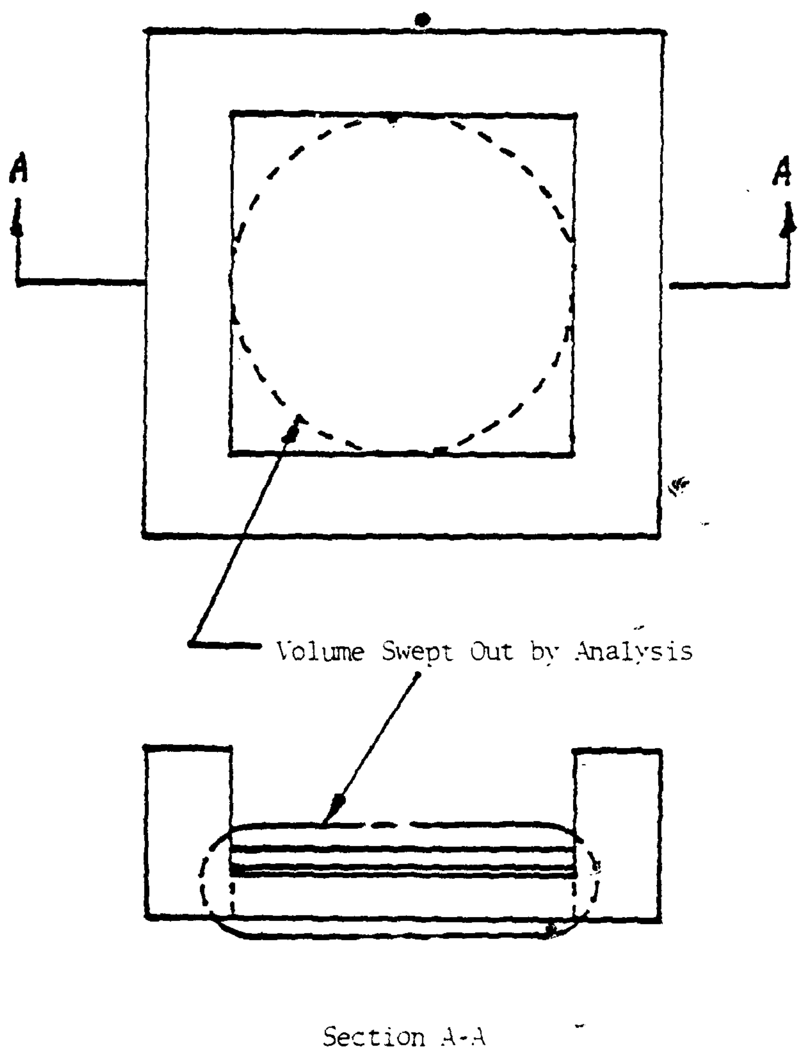


Figure 7.3-25. Module #5 Module Housing-Substrate Volume



7.3.10 Module #6 Epoxy Thermal Stresses

The module assembly drawing is shown in Figure 7.3-26. To evaluate the effect of bonding the substrate with epoxy to the module, an ANSYS axisymmetric analysis was performed. The same model as was used for Module #5 was used. A .003 in epoxy thickness was assumed.

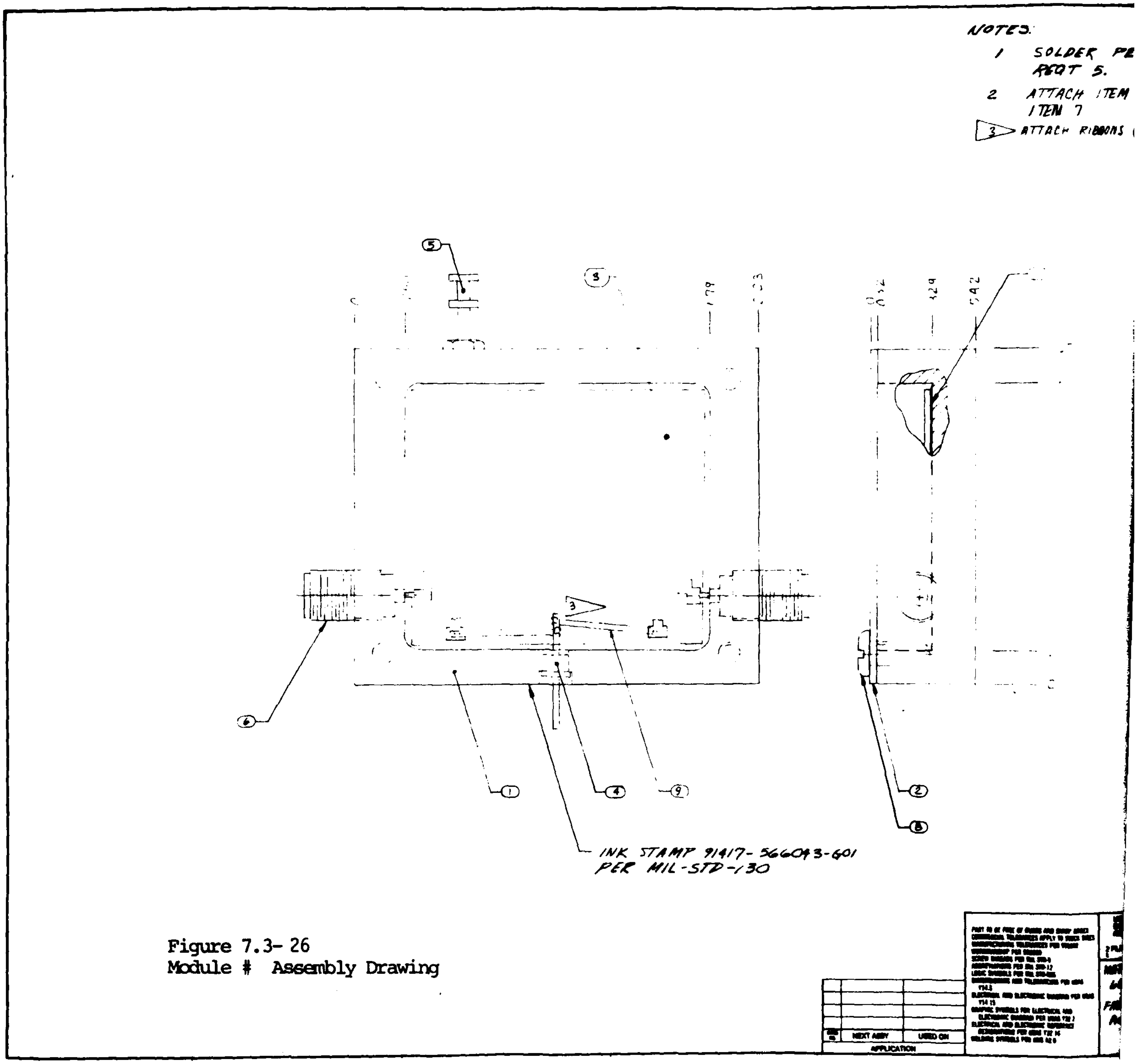
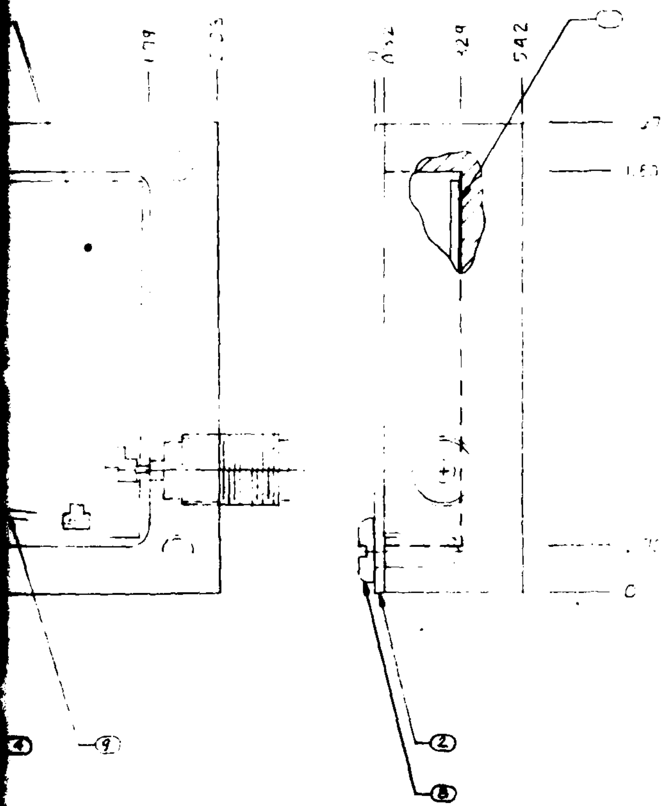


Figure 7.3- 26
Module # Assembly Drawing

REVISIONS				
ZONE	LTR	DESCRIPTION	DATE	APPROVED

NOTES:

1. SOLDER PER MIL-STD-454 REQT 5.
2. ATTACH ITEM 4 TO ITEM 1 USING ITEM 7.
3. ATTACH RIBBONS (ITEM 9) USING ITEM 7.



INK STAMP 91417-566043-601 PER MIL-STD-130

QTY	ITEM NO	PART OR IDENTIFYING NO	NOMENCLATURE OR DESCRIPTION	CODE IDENT
2	9	.025x.001	[illegible] 35 [illegible]	
4	8	MS51957-12	SCREW 4-40 [illegible]	
AR	7	3065 KAMAR [illegible]	[illegible]	
[illegible]	6	PDM 971	CONNECTOR	
1	5	2051-1	GROUND [illegible]	
1	4	9900-1X	FEED-THRU FILTER	
1	3	566042-601	AMPL FIELD	
1	2	566041-[illegible]	[illegible]	
1	1	566044-601	MODULE	

QUANTITY REQUIRED — LIST OF MATERIALS OR PARTS LIST

NEXT ASSY	USED ON
APPLICATION	

UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES AND INCLUDE APPLIED FINISH TOLERANCES 2 PLACE DIM. 3 PLACE DIM. ANGLES

MATL: ALUM ALLOY 6061-T6

FINISH: 50 μin Au PLATE

HARRIS ELECTRONIC SYSTEMS DIVISION MELBOURNE, FLORIDA 32901

TITLE: L-BAND AMPLIFIER MODULE ASSEMBLY

SIZE	CODE IDENT NO		REV
D	91417	566043	

SCALE | SHEET

REFERENCES

1. "A Methodology for Analysis of Fatigue in Solder Joints," L. J. Merrell, August, 1971.

SECTION 8.0

CONCLUSIONS AND RECOMMENDATIONS

8.0 SUMMARY

The conclusions and recommendations will be presented according to each section in this report. The conclusions represent a summary of MIC and Stripline information developed for this report.

The recommendations will be directed toward the need for additional work that must be accomplished with respect to construction methods, military standard amendments, and validation of computer analysis.

8.1 Conclusions

8.1.1 Microwave Integrated Circuit and Stripline Microwave Circuit Technologies

The data supplied by the various MIC and Stripline vendors clearly indicates that there are no standard procedures for the screening, lot conformance, or qualification testing of these products. The concept generally employed is that of vendor equivalent. Exceptions to MIL-STD-883B and MIL-M-38510 are the norm. Each vendor did document their respective procedures in order to maintain internal control of the quality and reliability of their respective products.

8.1.2 Preseal Visual Criteria for MIC and Stripline Microwave Circuits

Although it was found that vendors did document preseal visual criteria for their products, there was not always a general correlation to the criteria of MIL-STD-883B. The criteria developed for this program did incorporate much of the vendor's internal criteria.

8.1.3 Microwave Integrated Circuit and Stripline Microwave Circuit Tuning

Three specific types of tuning methods were documented in this report. As indicated in the MIL-M-38510, Appendix G evaluation, the tuning and Select at Test processes are considered rework; however, these processes must comply to MIL-M-38510 rework criteria.

8.1.4 MIL-M-38510, Appendix G Evaluation

It can be concluded that the general contents of Appendix G are not complied with by MIC vendors. MIC vendors perform the required rework to minimize cost escalations of their product and do not generally perform qualification or quality conformance testing. That is, the circuit or modules are repaired rather than discarded.

8.1.5 Dynamic and Thermal Stress Analysis of MIC and Stripline Construction Methods

No conclusions may be rendered at this time concerning the accuracy of computer analysis of construction methods. The analysis data may be considered 'predictors' until such time that the computer data is augmented by hardware evaluation. The analysis is by no means complete; however, it was an excellent beginning.

8.2 Recommendations

This program was the first step toward the objective of establishing screening, lot conformance, and qualification test methods for MIC and Stripline products used by the military. It was also the first step in developing computer analysis techniques as an evaluation of the various construction methods.

8.2.1 MIL-M-38510, Appendix G

The rework criteria, reseal criteria, and Group B testing must be reevaluated with respect to the cost and reliability of complex, single and multifunction MIC modules.

8.2.2 Dynamic and Thermal Stress Analysis

The accuracy of data generated by computer analysis of MIC and Stripline construction methods must be validated by data compiled by the screening of hardware. The MIC and Stripline industries should have sufficient data on their products to permit at least some correlation without the actual fabrication of hardware.

Additional effort is also required to discipline the computer analysis procedures; that is, establish set procedures that can be duplicated by companies within the industry. This computer analysis is not complete and additional work is required to apply the analysis to more broadly used MIC and Stripline products.

8.2.3 Pre-seal Burn-In

Pre-seal burn-in as relates to hermetically sealed MIC modules should be evaluated with respect to cost reductions associated with pre-seal burn-in. In conjunction with the pre-seal burn-in, the rework, allowable rework, of the circuits within the module shall also be evaluated.

It would be advantageous to perform a trade-off study of MIC's produced using pre-screened components against pre-seal burn-in, and allowable rework.

8.2.4 Seal Leak Testing

With the construction of MIC modules still consisting of SMA connectors, soldered in dc pins, and housing of various metals/alloys, Group D package evaluation must contain leak test procedures to assure the hermeticity of the various parts.

8.2.5 Mechanical Testing

Because of the large physical size and mass of the MIC and SMC modules, acceleration is not a applicable mechanical test; however, vibration and mechanical shock with magnitudes commensurate with the mission of the particular system should provide the necessary screening.

The conditions for the range of package sizes should be evaluated to assure that the package can withstand the levels of vibration and mechanical shock. (Computer analysis can provide a first order approximation).

8.3 Test Method Changes

RADC will coordinate the recommended changes to MIL-STD 883 and MIL-M-38510 which are reflected in the proposed test methods.

APPENDIX A

MIC VENDOR DATA

MIC MODULE COMPLEXITY

	MODULE NAME	FREQUENCIES: UHF	L BAND	S BAND	C BAND	X BAND	Ku BAND	OTHER	TECHNIQUE (S): THICK FILM MICROSTRIP	THIN FILM MICROSTRIP	P.C. BOARD MICROSTRIP	P.C. BOARD STRIPLINE	CAVITY	OTHER	# OF CIRCUITS/ SUBSTRATES: 1	2	3	4	5	MORE	MIL SPEC COMPLIANCE: YES	NO	CLAIMED	N/A	OTHER
1	DOWNCONVERTER	O	O							O												O			
2	COMPUTER WEIGHT		O							O												O			
3	PREAMP MIXER		O							O								O					O		
4	LO LOOP				O						O	O							O			O			
5	ANALOG PHASE SHIFTER					O	O				O	O					O					O			
6	UP CONVERTER	O			O					O	O									O			O		
7	DOWN CONVERTER	O					O			O										O					SPACE
8	RECEIVER FRONT END				O					O							O								O

THIN FILM HYBRID

	COMPONENTS																																							
	SUBSTRATE						CONDUCTOR ONLY METALLIZATION					RESISTOR/CONDUCTOR METALLIZATION							ACTIVE DEVICES													CAPACITORS						INDUCTORS		
	FREQUENCY	Al_2O_3	BeO	FUSED SILICA	SAPPHIRE	OTHER	Cr-Au	Mo-Au	Ti-Pt-Au	OTHER	OTHER	NiCr-Ni-Au	NiCr-Ti-Pt-Au	Ta_2N/Cr-Au	Ta_2N/Mo/Au	[illegible]-Au	[illegible]/Au	OTHER	PACKAGED	CHIP	BEAM LEAD	GaAs	Si	Al SOS	Al SOS	Si DOTTOP	AlSi DOTTOP	Ni/Au DOTTOP	OTHER	OTHER	OTHER	CERAMIC-END MET	CERAMIC-PARR PLATE	INTERDIGITAL	VARIABLE COMPONENT	SEMICONDUCTOR CHIP	OTHER	THIN FILM SPIRAL	AIR CORE	CHIP
1																																								
2																																								
3																																								
4																																								
5																																								
6																																								
7																																								
8																																								

THICK FILM TECHNOLOGY (CONT)

	PRODUCTS		COMPONENTS							ASSEMBLY																		TUNING METHODS										
			RESISTORS					DIELECTRIC LAYER		DIE ATTACH					DEVICE ATTACH						INTERCONNECT							WIRE BONDS				EPOXY				SCRIBING		
	MICROMINIATURE	OTHER	THIN FILM	THIN FILM CHIP	THICK FILM CHIP	SEMICONDUCTOR CHIP	OTHER	NONCONDUCTIVE EPOXY	OTHER	SILVER EPOXY	AuSi	AuGe	AuSn	OTHER	SILVER EPOXY	SOLDER	AuSn	NONCONDUCTIVE EPOXY	TC	OTHER	Au WIRE	Au RIBBON	Au MESH	Al WIRE	SILVER EPOXY	SOLDER	OTHER	ADDITION	REMOVAL	ORIENTATION	OTHER	ADDITION	SHORTING	DIELECTRIC OVERLAY	OTHER	LASER REMOVAL	ABRASIVE REMOVAL	OTHER
1					( )						( )				( )	( )	( )	( )	( )		( )	( )							( )			( )					( )	
2			( )								( )								( )		( )																( )	
3		ferrite bead								( )	( )						( )				( )							( )	( )									
4																																						
5																																						
6		ferrite bead	O							( )						( )							( )					( )	( )	( )		( )					( )	
7			O							( )			( )								( )	( )						( )	( )	( )								
8			O					O					O	SnPb								O																

TUNING METHODS	1	2	3	4	5	6	7	8
COMPONENT VAR.								
ACTIVE TRIMMING								
VARIABLE INDUCTORS								
VARIABLE CAPS								
CAP ARRAY CHIPS								
OTHER								

THICK FILM TECHNOLOGY

	COMPONENTS																													ASSEMBLY					
	SUBSTRATE				METALIZATION				ACTIVE DEVICES				CAPACITORS						INDUCTORS					RESISTORS					DIELECTRICS		DIE ATTACH				
	FREQUENCY	Al_2O_3	BeO	OTHER	Al	PdAg	PtAu	OTHER	PACKAGED	CHIP	BEAM LEAD	OTHER	THICK FILM	CERAMIC-END MET	CERAMIC-PARR PLATE	VARIABLE	INTERDIGITAL	OTHER	THICK FILM SPIRAL	AIR CORE	CHIP	MICROMINIATURE	OTHER	THICK FILM	THIN FILM CHIP	THICK FILM CHIP	SEMICONDUCTOR CHIP	OTHER	THICK FILM	NON-CONDUCTIVE EPOXY	SILVER EPOXY	AuSi	AuGe	AuSn	OTHER
1																																			
2																																			
3																																			
4																																			
5																																			
6																																			
7																																			
8																																			

	ASSEMBLY														TUNING																OTHER
	DEVICE ATTACH						INTERCONNECT								Wire BONDS				EPOXY				SCRIBING			COMPONENT ADJUST					
	Silver EPOXY	SOLDER	AuSn	NON-CONDUCTIVE EPOXY	TC	OTHER	THICK FILM CROSS OVER	AuWIRE	Au RIBBON	Au MESH	Al WIRE	SILVER EPOXY	SOLDER	OTHER	ADDITION	REMOVAL	ORIENTATION	OTHER	ADDITION	SHORTING	DIELECTRIC OVERLAY	OTHER	LASER REMOVAL	ABRASIVE REMOVAL	OTHER	ACTIVE TRIMMING	INDUCTOR SLUGS	ADJUSTABLE CAPS	CAP ARRAY CHIPS	OTHER	
1																															
2																															
3																															
4																															
5																															
6																															
7																															
8																															

[illegible]

PACKAGE									
TYPE	MACHINED BOX	O	O				O	O	O
	DRAWN BOX								
	BRAZED BOX			O					
	HEADER								
	MULTIPLE CAVITY	O							
	MODULE IN A MODULE								KOVAR CARRIER
	OTHER								
	OTHER								
MATERIAL	KOVAR			O					
	ALUMINUM	O	O				O	O	O
	STEEL			O					
	COPPER								
	BRASS								
	OTHER								
PLATING	NONE							O	
	Ni/Au	O	O	O			O		
	Au								
	Ni								
	OTHER								O
PAINT	NONE			O					
	OIL BASE								
	EPOXY BASE	O	O				O	O	O
	OTHER								
SEALING METHOD	WELD			O				O	
	SOLDER								
	BRAZE								
	EPOXY	O	O				O		O
	GASKET								
	GLASS								
	MECHANICAL								
	NONE								
	OTHER								
VOLUME (V) (CU IN)	<0.125								
	0.125≤V≤0.25								
	0.25≤V≤0.50								
	0.50≤V≤1.0								O
	1.0≤V≤2.0	O	O	O			O	O	
	2.0≤V≤4.0								
	4.0≤V≤8.0								
	8.0≤V								

THICK AND THIN FILM PACKAGING AND INTEGRATION (CONT)

	PACKAGING						SUBSTRATE INTEGRATION																TUNING										
	I/O INTERFACE						SUBSTRATE BONDING					INTERCONNECTION						BACK FILL GAS					PACKAGE							SUBSTRATE			
	BRAZED-GLASS/ METAL	SOLDERED-GLASS/ METAL	MECHANICAL-COMPRESSION	SCREW-ON	RIGHT ANGLE	PLANER LAUNCH	EPOXY	SOLDER	BRAZE	CLAMPS	SUBSTRATE CARRIER	WELDED RIBBON	EPOXIED RIBBON	SOLDERED WIRE	WIRE BOND	CLAMP (GND)	OTHER	DRY AIR	NITROGEN	VACUUM	HELIUM	OTHER	COVER HEIGHT	CHANNEL WIDTH	CHANNEL LENGTH	RF ABSORBER	PLATING	CONDUCTIVE POSTS	OTHER	SIZE	DIELECTRIC CHIPS	ORIENTATION	OTHER
1			O							O	O				O				O		O			O			O			O			
2			O							O					O				O		O			O			O			O			
3	O						O								O				O		O			O			O			O			
4																								O									
5																																	
6		O						O	O	O		O		O	O			O								O				O			
7			O						O	O		O							O							O				O			
8					O	O		O	O		O							O					O	O							O		O

MIC MODULE COMPLEXITY

MODULE NAME	FREQUENCIES							TECHNIQUE (S)						# OF CIRCUITS/ SUBSTRATES						MIL SPEC COMPLIANCE				
	UHF	L BAND	S BAND	C BAND	X BAND	Ku BAND	OTHER	THICK FILM MICROSTRIP	THIN FILM MICROSTRIP	P.C. BOARD MICROSTRIP	P.C. BOARD STRIPLINE	CAVITY	OTHER	1	2	3	4	5	MORE	YES	NO	CLAIMED	N/A	OTHER
9. VOLTAGE TUNED CONVERTER		O	O	O	O						O	COAX				O					O			
10. SHF DOWN CONVERTER	O			O	O				O	O	O								O			O		
11. DOWN CONVERTER	O			O					O										O					O
12. COMPLEX WEIGHT	O							O	O								O				O			
13. CORRELATOR	O								O								O				O			
14. ARRAY SUMMER	O								O										6		O			
15. CHANNEL DROP DIPLEXER					O						O					O					O			
16. DIODE SCANNER FOR PSEUDOMONOPULSE			O								O						O				O			

THIN FILM TECHNOLOGY

COMPONENTS		9	10	11	12	13	14	15	16
INDUCTORS	CHIP			O					
	AIR CORE		O	O					
	THIN FILM SPIRAL				O	O	O		
CAPACITORS	OTHER								
	SEMICONDUCTOR CHIP								
	VARIABLE COMPONENT								
	INTERDIGITAL			O					
	CERAMIC-PARR PLATE			O	O	O	O		
	CERAMIC-ENC MET		O	O		O	O		
ACTIVE DEVICES	OTHER								
	OTHER								
	OTHER								
	Ni/Au bottom						O		
	AuSi bottom					O	O		
	Si bottom								
	Al top					O	O		
	Au top						O		
	Si					O	O		
	GaAs								
	BEAM LEAD			O					
	CHIP					O	O		
	PACKAGE		O						
RESISTOR/CONDUCTOR METALIZATION	TaN_2/Ti/Pt/Au								
	NiCr/Au		O	O					
	TaN_2/Mo/Au								
	TaN_2/Cr/Au								
	NiCr/Ti/Ni/Au				O	O	O		
	NiCr/Ni/Au								
CONDUCTOR ONLY METALIZATION	NiCr/Au			O					
	OTHER								
	TiPt/Au								
	Mo/Au								
	Cr/Au		O		O		O		
SUBSTRATE	OTHER								
	SAPPHIRE								
	FUSED SILICA								
	BeO_2								
	Al_2O_3		O		O	O	O		
	FREQUENCY								

THIN FILM TECHNOLOGY (CONT)

	COMPONENTS: INDUCTORS: MICROMINIATURE	COMPONENTS: INDUCTORS: OTHER	COMPONENTS: RESISTORS: THIN FILM	COMPONENTS: RESISTORS: THIN FILM CHIP	COMPONENTS: RESISTORS: THICK FILM CHIP	COMPONENTS: RESISTORS: SEMICONDUCTOR CHIP	COMPONENTS: RESISTORS: OTHER	COMPONENTS: DIELECTRIC LAYER: NONCONDUCTIVE EPOXY	COMPONENTS: DIELECTRIC LAYER: OTHER	ASSEMBLY: DIE ATTACH: SILVER EPOXY	ASSEMBLY: DIE ATTACH: AuSn	ASSEMBLY: DIE ATTACH: AuGe	ASSEMBLY: DIE ATTACH: AuSi	ASSEMBLY: DIE ATTACH: OTHER	ASSEMBLY: DEVICE ATTACH: SILVER EPOXY	ASSEMBLY: DEVICE ATTACH: SOLDER	ASSEMBLY: DEVICE ATTACH: AuSn	ASSEMBLY: DEVICE ATTACH: NONCONDUCTIVE EPOXY	ASSEMBLY: DEVICE ATTACH: TC	ASSEMBLY: DEVICE ATTACH: OTHER	ASSEMBLY: INTERCONNECT: Au WIRE	ASSEMBLY: INTERCONNECT: Au RIBBON	ASSEMBLY: INTERCONNECT: Au MESH	ASSEMBLY: INTERCONNECT: Al WIRE	ASSEMBLY: INTERCONNECT: SILVER EPOXY	ASSEMBLY: INTERCONNECT: SOLDER	ASSEMBLY: INTERCONNECT: OTHER	TUNING METHODS: WIRE BONDS: ADDITION	TUNING METHODS: WIRE BONDS: REMOVAL	TUNING METHODS: WIRE BONDS: ORIENTATION	TUNING METHODS: WIRE BONDS: OTHER	TUNING METHODS: EPOXY: ADDITION	TUNING METHODS: EPOXY: SHORTING	TUNING METHODS: EPOXY: DIELECTRIC OVERLAY	TUNING METHODS: EPOXY: OTHER	TUNING METHODS: SCRIBING: LASER REMOVAL	TUNING METHODS: SCRIBING: ABRASIVE REMOVAL	TUNING METHODS: SCRIBING: OTHER
9																																						
10	( )		( )	( )				( )						Sn Pb Ag														( )	( )									
11								( )						8L		( )						( )						( )								( )		( )
12	O		O		O					O							( )				( )	( )									( )							
13	O				O					O	O					O	( )				O	O									( )							
14	O		O		O					O	O					O	O				O	O									( )							
15																																						
16																																						

THIN FILM TECHNOLOGY (CONT)

	TUNING METHODS					
	COMPONENT VAR.					
	ACTIVE TRIMMING	VARIABLE INDUCTORS	VARIABLE CAPS	CAP ARRAY CHIPS	OTHER	
9						
10						
11						
12						
13						
14						
15						
16						

THICK FILM HYBRID

			9	10	11	12	13	14	15	16
	SUBSTRATE	FREQUENCY								
		Al_2O_3				O				
		BeO								
		OTHER								
	METALLIZATION	Au				O				
		PdAg								
		PtAu								
		OTHER								
	ACTIVE DEVICES	PACKAGED								
		CHIP				O				
		BEAM LEAD								
		OTHER								
COMPONENTS	CAPACITORS	THICK FILM								
		CERAMIC-END MET				O				
		CERAMIC-PARR PLATE								
		VARIABLE								
		INTERDIGITAL								
		OTHER								
	INDUCTORS	THICK FILM SPIRAL								
		AIR CORE								
		CHIP								
		MICROMINIATURE				O				
		OTHER								
	RESISTORS	THICK FILM				O				
		THIN FILM CHIP								
		THICK FILM CHIP								
		SEMICONDUCTOR CHIP								
		OTHER								
	DIELECTRICS	THICK FILM								
		NON-CONDUCTIVE EPOXY								
ASSEMBLY	DIE ATTACH	SILVER EPOXY				O				
		AuSi				O				
		AuGe								
		AuSn								
		OTHER								

	OTHER	TUNING											
		COMPONENT ADJUST					SCRIBING			EPOXY			
		OTHER	CAP ARRAY CHIPS	ADJUSTABLE CAPS	INDUCTOR SLUGS	ACTIVE TRIMMING	OTHER	ABRASIVE REMOVAL	LASER REMOVAL	OTHER	DIELECTRIC OVERLAY	SHORTING	ADDITION
9													
10													
11													
12													
13													
14													
15													
16													

	TUNING			
	WIRE BONDS			
	OTHER	ORIENTATION	REMOVAL	ADDITION
9				
10				
11				
12				
13				
14				
15				
16				

	ASSEMBLY													
	INTERCONNECT								DEVICE ATTACH					
	OTHER	SOLDER	SILVER EPOXY	Al WIRE	Au MESH	Au RIBBON	AuWIRE	THICK FILM CROSS OVER	OTHER	[illegible]	NON-CONDUCTIVE EPOXY	AuSi	SOLDER	SILVER EPOXY
9														
10														
11														
12														
13														
14														
15														
16														

THICK AND THIN FILM PACKAGING AND INTEGRATION

	PACKAGE																																							
	TYPE								MATERIAL						PLATING					PAINT				SEALING METHOD									VOLUME (V) (CU IN)							
	MACHINED BOX	DRAWN BOX	BRAZED BOX	HEADER	MULTIPLE CAVITY	MODULE IN A MODULE	OTHER	OTHER	KOVAR	ALUMINUM	STEEL	COPPER	BRASS	OTHER	NONE	NI/AU	AU	NI	OTHER	NONE	OIL BASE	EPOXY BASE	OTHER	WELD	SOLDER	BRAZE	EPOXY	GASKET	GLASS	MECHANICAL	NONE	OTHER	<0.125	0.125≤V<0.25	0.25≤V<0.50	0.50≤V<1.0	1.0≤V<2.0	2.0≤V<4.0	4.0≤V<6.0	6.0≤V
9																																								
10	( )				( )	( )				( )						( )				( )											O									O
11	( )									( )						( )						O															O			
12	O									O						O						O					O			O							O			
13	O									O						O						O					O			O							O			
14	O									O						O						O					O			O							O			
15																																								
16																																								

THICK AND THIN FILM MIC MFG. AND INTEGRATION (CONT)

	PACKAGING						SUBSTRATE INTEGRATION																TUNING										
	I/O INTERFACE						SUBSTRATE BONDING					INTERCONNECTION						BACK FILL GAS					PACKAGE							SUBSTRATE			
	BRAZED-GLASS METAL	SOLDERED-GLASS METAL	MECHANICAL COMPRESSION	SCREW-ON	RIGHT ANGLE	PLANER LAUNCH	EPOXY	SOLDER	BRAZE	CLAMPS	SUBSTRATE CARRIER	WELDED RIBBON	EPOXIED RIBBON	SOLDERED WIRE	WIRE BOND	CLAMP (GAP)	OTHER	DRY AIR	NITROGEN	VACUUM	HELIUM	OTHER	COVER HEIGHT	CHANNEL WIDTH	CHANNEL LENGTH	RF ABSORBER	PLATING	CONDUCTIVE POSTS	OTHER	SIZE	DIELECTRIC CHIPS	ORIENTATION	OTHER
10				o		o	O			O	O	O		O		O																	
11			o	o		o				O		O			O				O														
12		o				o				O		O	O			O			o										O				
13		o				O				O		O	O			O			o										O				
14		O				O				O		O	O			O			O				O						O				
15																																	
16																																	

MIC MODULE COMPLEXITY

	MODULE NAME		FREQUENCIES						TECHNIQUE (S)						# OF CIRCUITS/ SUBSTRATES						MIL-SPEC COMPLIANCE				
		UHF	L BAND	S BAND	C BAND	X BAND	Ku BAND	OTHER	THICK FILM MICROSTRIP	THIN FILM MICROSTRIP	P.C. BOARD MICROSTRIP	P.C. BOARD STRIPLINE	CAVITY	OTHER	1	2	3	4	5	MORE	YES	NO	CLAIMED	N/A	OTHER
17	QUADRATURE FEED NETWORKS		O	O	O							O			O							O			
18	POWER DIVIDERS	O										O								O		O			
19	ARRAY BUTLER MATRIX FEED									O									O			O			
20	SPIRAPHASE PHASE SHIFTERS		O		O					O					O							O			
21	9 BIT PHASE SHIFTERS				O					O						O						O			
22	J BAND MIXER					O				O								O				O			
23																									
24																									

THIN FILM TECHNOLOGY

COMPONENTS		17	18	19	20	21	22	23	24
INDUCTORS	CHIP						O		
	AIR CORE								
	THIN FILM SPIRAL				O				
CAPACITORS	OTHER								
	SEMICONDUCTOR CHIP				O	O	O		
	VARIABLE COMPONENT								
	INTERDIGITAL								
	CERAMIC-PARR PLATE						O		
	CERAMIC-ENC MET								
ACTIVE DEVICES	OTHER								
	OTHER								
	OTHER								
	Ni/Au bottom								
	AuSi bottom				O	O			
	Si bottom								
	Al top								
	Au top				O	O			
	Si						O		
	GaAs								
	BEAM LEAD						O		
	CHIP				O	O			
	PACKAGED								
RESISTOR/CONDUCTOR METALLIZATION	OTHER								
	OTHER								
	OTHER								
	TaN2/Mo/Au								
	TaN2/Cr/Au								
	NiCr/Ti/Pt/Au								
	NiCr/Ni/Au								
CONDUCTOR ONLY METALLIZATION	OTHER								
	OTHER								
	TiPt/Au								
	Mo/Au								
	Cr/Au			O	O	O	O		
SUBSTRATE	OTHER								
	SAPPHIRE								
	FUSED SILICA						O		
	BeO								
	Al_2O_3			O	O	O			
	FREQUENCY								

THIN FILM [illegible] (CONT)

	COMPONENTS									ASSEMBLY																		TUNING METHODS										
	INDUCTORS		RESISTORS					DIELECTRIC LAYER		DIE ATTACH					DEVICE ATTACH						INTERCONNECT							WIRE BONDS				EPOXY				SCRIBING		
	MICROMINIATURE	OTHER	THIN FILM	THIN FILM CHIP	THICK FILM CHIP	SEMICONDUCTOR CHIP	OTHER	NONCONDUCTIVE EPOXY	OTHER	SILVER EPOXY	AuSi	AuGe	AuSn	OTHER	SILVER EPOXY	SOLDER	AuSn	NONCONDUCTIVE EPOXY	TC	OTHER	AU WIRE	AU RIBBON	AU MESH	AL WIRE	SILVER EPOXY	SOLDER	OTHER	ADDITION	REMOVAL	ORIENTATION	OTHER	ADDITION	SHORTING	DIELECTRIC OVERLAY	OTHER	LASER REMOVAL	ABRASIVE REMOVAL	OTHER
17																																						
18																																						
19																						O			O													
20											( )				( )						O	O				O												
21															( )						O	O															O	
22														( )				( )				O															O	
23																																						
24																																						

THIN FILM TECHNOLOGY (CONT)

	TUNING METHODS					
	COMPONENT VAR.					
	ACTIVE TRIMMING	VARIABLE INDUCTORS	VARIABLE CAPS	CAP ARRAY CHIPS	OTHER	
17						
18						
19						
20						
21						
22						
23						
24						

THICK FILM TECHNOLOGY

	COMPONENTS																														ASSEMBLY					
	SUBSTRATE				METALIZATION				ACTIVE DEVICES				CAPACITORS						INDUCTORS					RESISTORS					DIELECTRICS		DIE ATTACH					
	FREQUENCY	Al_2O_3	BeO	OTHER	Au	PdAg	PtAu	OTHER	PACKAGED	CHIP	BEAM LEAD	OTHER	THICK FILM	CERAMIC-ENC MET	CERAMIC-PARR PLATE	VARIABLE	INTERDIGITAL	OTHER	THICK FILM SPIRAL	AIR CORE	CHIP	MICROMINATURE	OTHER	THICK FILM	THIN FILM CHIP	THICK FILM CHIP	SEMICONDUCTOR CHIP	OTHER	THICK FILM	NON-CONDUCTIVE EPOXY	SILVER EPOXY	AuSn	AuGe	AuSi	OTHER	
17																																				
18																																				
19																																				
20																																				
21																																				
22																																				
23																																				
24																																				

	ASSEMBLY														TUNING																OTHER
	DEVICE ATTACH						INTERCONNECT								WIRE BONDS				EPOXY				SCRIBING			COMPONENT ADJUST					
	Silver EPOXY	SOLDER	AuSi	NON-CONDUCTIVE EPOXY	TC	OTHER	THICK FILM CROSS OVER	AuWIRE	Au RIBBON	Au MESH	Al WIRE	SILVER EPOXY	SOLDER	OTHER	ADDITION	REMOVAL	ORIENTATION	OTHER	ADDITION	SHORTING	DIELECTRIC OVERLAY	OTHER	LASER REMOVAL	ABRASIVE REMOVAL	OTHER	ACTIVE TRIMMING	INDUCTOR SLUGS	ADJUSTABLE CAPS	CAP ARRAY CHIPS	OTHER	
17																															
18																															
19																															
20																															
21																															
22																															
23																															
24																															

THICK AND THIN FILM PACKAGING AND INTEGRATION

	PACKAGE																																							
	TYPE								MATERIAL						PLATING					PAINT				SEALING METHOD									VOLUME (V) (CU IN)							
	MACHINED BOX	DRAWN BOX	BRAZED BOX	HEADER	MULTIPLE CAVITY	MODULE IN A MODULE	OTHER	OTHER	KOVAR	ALUMINUM	STEEL	COPPER	BRASS	OTHER	NONE	Ni/Au	Au	Ni	OTHER	NONE	OIL BASE	EPOXY BASE	OTHER	WELD	SOLDER	BRAZE	EPOXY	GASKET	GLASS	MECHANICAL	NONE	OTHER	<0.125	0.125≤V≤0.25	0.25≤V≤0.50	0.50≤V≤1.0	1.0≤V≤2.0	2.0≤V≤4.0	4.0≤V≤8.0	>8.0
17																																								
18																																								
19							O							O						O											O									
20							O							O						O											O									
21	O									O							O			O											O				O					
22	O									O																	O									O				
23																																								
24																																								

THICK AND THIN FILM PACKAGING AND INTEGRATION (CONT)

	PACKAGING						SUBSTRATE INTEGRATION																TUNING										
	I/O INTERFACE						SUBSTRATE BONDING					INTERCONNECTION						BACK FILL GAS					PACKAGE							SUBSTRATE			
	BRAZED-GLASS METAL	SOLDERED-GLASS/ METAL	MECHANICAL-COMPRESSION	SCREW-ON	RIGHT ANGLE	PLANER LAUNCH	EPOXY	SOLDER	BRAZE	CLAMPS	SUBSTRATE CARRIER	WELDED RIBBON	EPOXIED RIBBON	SOLDERED WIRE	WIRE BOND	CLAMP (GND)	OTHER	DRY AIR	NITROGEN	VACUUM	HELIUM	OTHER	COVER HEIGHT	CHANNEL WIDTH	CHANNEL LENGTH	RF ABSORBER	PLATING	CONDUCTIVE POSTS	OTHER	SIZE	DIELECTRIC CHIPS	ORIENTATION	OTHER
17																																	
18																																	
19							O					O																					
20														O																			
21					O					O		O																					
22	O		O		O	O				O	O	O											O	O					O				
23																																	
24																																	

APPENDIX B

STRIPLINE VENDOR DATA

PRINTED CIRCUIT TECHNOLOGY

	BOARD																												COMPONENTS										
	DIELECTRIC													METALIZATION						DIELECTRIC THICKNESS									ACTIVE DEVICE						CAPACITORS				
	[illegible]	TEFLON	REXOLITE	TEFLON WOVEN FIBERGLASS	TEFLON CHOPPED FIBERGLASS	POLYOLEFIN	POLYSTYRENE	GLASS REINFORCED POLYSTYRENE	POLYPHENYLENE OXIDE PPO	CERAMIC-FILLED RESINS	TEFLON-QUARTZ	OTHER	OTHER	1/4 OZ CU	1/2 OZ CU	1.0 OZ CU	2.0 OZ CU	ALUMINUM	OTHER	10 MIL	15 MIL	20 MIL	25 MIL	31 MIL	62 MIL	125 MIL	OTHER	OTHER	CHIP	CERAMIC-PLUG-IN PACKAGE	CERAMIC SCREW IN HEAT SINK	CERAMIC FLAT RADIAL LEADS	OTHER	OTHER	CHIP	PILL SHAPE	STUB	INTERDIGITATED	OTHER
1 Down-converter																																							
2 Complex Weight																																							
3 Preamp Module																																							
4 DCV-1000				O											O									O								O			O				
5 Analog Phase Shifter				O											O									O								O			O				
6 Up-converter																																							
7 Down-converter																																							
8 Receiver Front End																																							

SPIRAL								
STUD								
CHIP								
OTHER				O	O			
ROD TYPE								
PILL SHAPE								
DISC TYPE								
STUD MOUNTED								
CHIP				O	O			
OTHER					CARBON			
CARTRIDGE								
FLANGE								
PILL SHAPE				O	O			
CHIP				O	O			
SMA FLANGE								
OTHER								
FLANGE MOUNTED								
SMA FLANGE								
THIN FILM CHIP								
PILL SHAPE								
CONDUCTION COOLED								
OTHER								
SOLDER LEAD				O	O			
EPOXY LEADS								
MECHANICAL SCREW								
MECHANICAL PRESSURE								
SOCKET								
RIBBON								
OTHER					Non-Conductive Epoxy			
EPOXY RIBBON								
SOLDER RIBBON								
DEVICE								
SOLDER TABS					O			
THRU HOLES					O			
NONE ALL COMP ON ONE PIC BOARD								
WIRE BOND								
OTHER								

PRINTED CIRCUIT (CONT)

	ASSEMBLY								TUNING			
	GROUND								PRE ASSEMBLY			
	MECH SCREW	MECH PRESSURE	PLATED THRU HOLES	RIBBON	RIVETS	EYELETS	CLAMPS	OTHER	SCRIBING	DIELECTRIC LOADING	FERRITE LOADING	INDUCTOR WIRE ORIENTATION
1												
2												
3												
4			O						O			O
5			O									
6												
7												
8												

		1	2	3	4	5	6	7	8
PACKAGE SEALING METHOD	OTHER								
	NONE				O	O			
	GLASS SEALS								
	METAL TAPE								
	WELDING								
	EDGE SOLDER								
	RUBBER GASKET								
	EPOXY ENCAPSULATION								
DIELECTRIC BONDING MATERIALS	OTHER								
	NONE				O				
	GREASE								
	GLUE								
	EPOXY								
	PLASTIC FILM					O			
VOLUME (V) (CU. IN.)	$V > 8.0$				O				
	$4.0 \leq V \leq 8.0$								
	$2.0 \leq V \leq 4.0$								
	$1.0 \leq V \leq 2.0$								
	$0.5 \leq V \leq 1.0$								
	$V \leq 0.5$								
# OF CIRCUITS/ SUBSTRATES	MORE								
	5				O				
	4								
	3					O			
	2								
	1								
GND PLANE MAT.	OTHER								
	BRASS								
	STEEL								
	KOVAR								
	ALUMINUM				O	O			
	COPPER					O			
CONSTRUCTION	OTHER								
	METAL CANS								
	BONDED STRIPLINE				O	O			
	BOX AND COVER								
	CHANNELIZED CHASSIS				O	O			
	BONDED METAL								
	FLAT PLATE								

PACKAGING P.C. BOARD (CONT)

	SEAL MATERIAL								INTERFACE									OTHER		
	CONDUCTIVE EPOXY	INSULATIVE EPOXY	CONDUCTIVE GASKET	NON-CONDUCTIVE GASKET	SOLDER	COPPER TAPE	KOVAR GLASS	OTHER	ENC LAUNCH	BROADWALL LAUNCH	PRESSED IN PIN	TNC	BNC	SMA	N TYPE	SOLDER TABS	OTHER	STRIPLINE	MICROSTRIP	COST
1																				
2																				
3																				
4									O					O	O			O	O	$1,000.00
5									O					O				O	O	
6																				
7																				
8																				

PRINTED CIRCUIT TECHNOLOGY

	BOARD																													COMPONENTS									
	DIELECTRIC													METALLIZATION						DIELECTRIC THICKNESS									ACTIVE DEVICE						CAPACITORS			
	G10	TEFLON	REXOLITE	TEFLON WOVEN FIBERGLASS	TEFLON IMPREG FIBERGLASS	POLYOLEFIN	POLYPROPYLENE	GLASS REINFORCED POLYPROPYLENE	POLYPHENYLENE OXIDE PPO	CERAMIC-FILLED RESINS	TEFLON-QUARTZ	OTHER	OTHER	1/4 oz Cu	1/2 oz Cu	1 oz Cu	2 oz Cu	ALUMINUM	OTHER	10 mil	15 mil	20 mil	25 mil	[illegible] mil	62 mil	125 mil	OTHER	OTHER	CHIP	CERAMIC-FLAT IN PACKAGE	CERAMIC SCREW IN HEAT SINK	CERAMIC FLAT RADIAL LEADS	OTHER	OTHER	CHIP	FULL SHAPE	STUB	INTERDIGITATED
9 Voltage Tuned Oscillator									[illegible]							O									O					O								
10 SHF Down Converter	O				O											O									O								[illegible]		O			O
11 Down-converter																																						
12 Complex Weight																																						
13 Correlator																																						
14 Array Summer																																						
15 Channel Drop Diplexer					O											O				O					O													
16 Mode Scanner for Pseudomonopulse					O											O				O					O						O					O		

PRINTED CIRCUIT (CONT)

	COMPONENTS																						ASSEMBLY															
	INDUCTOR				RESISTOR						TERMINATIONS						ATTENUATORS						COMPONENTS							INTERCONNECTS								
	SPIRAL	STUD	CHIP	OTHER	ROD TYPE	PILL SHAPE	DISC TYPE	STUD MOUNTED	CHIP	OTHER	CARTRIDGE	FLANGE	PILL SHAPE	CHIP	SMA FLANGE	OTHER	FLANGE MOUNTED	SMA FLANGE	THIN FILM CHIP	PILL SHAPE	CONDUCTION COOLED	OTHER	SOLDER LEAD	EPOXY LEADS	MECHANICAL SCREW	MECHANICAL PRESSURE	SOCKET	RIBBON	OTHER	EPOXY RIBBON	SOLDER RIBBON	DEVICE	SOLDER TABS	THRU HOLES	NONE (ALL COMP ON ONE P.C. BOARD)	WIRE BOND	OTHER
9						O														O								O				O		O			
10									O	O				O	O	O						O	O					O			O			O			
11																																					
12																																					
13																																					
14																																					
15																																			O		
16													O												O	O									O		

PRINTED CIRCUIT (CONT)

	ASSEMBLY								TUNING		
	GROUND								PRE-ASSEMBLY		
	MECH. SCREW	MECH. PRESSURE	PLATED THRU HOLES	RIBBON	RIVETS	EYELETS	CLAMPS	OTHER	SCRIBING	DIELECTRIC LOADING	FERRITE LOADING
9	O	O									
10	O	O	O	O			O		O		
11											
12											
13											
14											
15		O									
16			O								

PACKAGING P.C. BOARD

		9	10	11	12	13	14	15	16
CONSTRUCTION	FLAT PLATE		O					O	
	BONDED METAL								
	CHANNELLED CHASSIS		O						
	BOX AND COVER		O						O
	BONDED STRIPLINE		O						
	METAL CANS								
	OTHER		O						
GND PLANE MAT.	COPPER	O							
	ALUMINUM							O	O
	KOVAR								
	STEEL								
	BRASS	O	O						
	OTHER								
# OF CIRCUITS/SUBSTRATES	1	O							
	2								
	3							O	
	4								O
	5								
	MORE		O						
VOLUME (V) (Cu IN.)	V ≤ 0.5							O	
	0.5 < V ≤ 1.0								
	1.0 < V ≤ 2.0								O
	2.0 < V ≤ 4.0	O							
	4.0 < V ≤ 8.0								
	V > 8.0								
DIELECTRIC BONDING MATERIAL	PLASTIC FILM								
	EPOXY								
	GLUE								
	GREASE								
	NONE							O	O
	OTHER								
PACKAGE SEALING METHOD	EPOXY ENCAPSULATION								
	RUBBER GASKET								
	EDGE SOLDER								
	WELDING								
	METAL TAPE								
	GLASS SEALS								
	NONE							O	O
	OTHER								

[illegible]

	[illegible]								INTERFACE									OTHER
	CONDUCTIVE EPOXY	INSULATIVE EPOXY	CONDUCTIVE GASKET	NON-CONDUCTIVE GASKET	SOLDER	COPPER TAPE	KOVAR GLASS	OTHER	WIRE LAUNCH	BROADWALL LAUNCH	GLASSED IN PIN	TNC	BNC	SMA	N TYPE	SOLDER TABS	OTHER	
9	O								O					O			100% COAXIAL CABLE	
10									O					O				
11																		
12																		
13																		
14																		
15									O		O			O				
16									O		O			O				

HYBRID CIRCUIT TECHNOLOGY

	BOARD												
	DIELECTRIC												
	G10	TEFLON	REXOLITE	TEFLON/WOVEN FIBERGLASS	TEFLON/CHOPPED FIBERGLASS	POLYOLEFIN	POLYSTYRENE	GLASS REINFORCED POLYSTYRENE	POLYPHENYLENE OXIDE (PPO)	CERAMIC-FILLED RESINS	TEFLON-QUARTZ	OTHER	OTHER
17 Quadrature Feed Networks					( )	( )							
18 Power Dividers				( )									
19 Array Butler Matrix Feed													
20 Spiraphase Phase Shifters													
21 9-Bit Phase Shifters													
22 J-Band Mixer													
23													
24													

	BOARD														
	METALLIZATION						DIELECTRIC THICKNESS								
	1/4 oz Cu	1/2 oz Cu	1.0 oz Cu	2.0 oz Cu	ALUMINUM	OTHER	10 MIL	15 MIL	20 MIL	25 MIL	31 MIL	62 MIL	125 MIL	OTHER	OTHER
17 Quadrature Feed Networks			( )								( )	( )			
18 Power Dividers			( )									( )			
19 Array Butler Matrix Feed															
20 Spiraphase Phase Shifters															
21 9-Bit Phase Shifters															
22 J-Band Mixer															
23															
24															

	COMPONENTS										
	ACTIVE DEVICE						CAPACITORS				
	CHIP	CERAMIC-PLUG-IN PACKAGE	CERAMIC, SCREW IN HEAT SINK	CERAMIC, FLAT RADIAL LEADS	OTHER	OTHER	CHIP	FILM SHAPE	STUB	INTERDIGITATED	OTHER
17 Quadrature Feed Networks											
18 Power Dividers											
19 Array Butler Matrix Feed											
20 Spiraphase Phase Shifters											
21 9-Bit Phase Shifters											
22 J-Band Mixer											
23											
24											

PRINTED CIRCUIT (CONT)

	COMPONENTS																						ASSEMBLY															
	INDUCTOR				RESISTOR						TERMINATIONS						ATTENUATORS						COMPONENTS							INTERCONNECTS								
	SPIRAL	STUB	CHIP	OTHER	RDC TYPE	PILL SHAPE	DISC TYPE	STUD MOUNTED	CHIP	OTHER	CARTRIDGE	FLANGE	PILL SHAPE	CHIP	SMA FLANGE	OTHER	FLANGE MOUNTED	SMA FLANGE	THIN FILM CHIP	PILL SHAPE	CONDUCTION COOLED	OTHER	SOLDER LEAD	EPOXY LEADS	MECHANICAL, SCREW	MECHANICAL, PRESSURE	SOCKET	RIBBON	OTHER	EPOXY RIBBON	SOLDER RIBBON	DEVICE	SOLDER TABS	THRU HOLES	NONE (ALL COMP ON ONE P.C. BOARD)	WIRE BOND	OTHER	
17																																			O			
18									O														O												O			
19																																						
20																																						
21																																						
22																																						
23																																						
24																																						

PRINTED CIRCUIT (CONT)

	ASSEMBLY								TUNING			
	GROUND								PRE-ASSEMBLY			
	MECH SCREW	MECH. PRESSURE	PLATED THRU HOLES	RIBBON	RIVETS	EYELETS	CLAMPS	OTHER	SCRIBING	DIELECTRIC LOADING	FERRITE LOADING	
17		O										
18		O										
19												
20												
21												
22												
23												
24												

PACKAGING BOARD

		17	18	19	20	21	22	23	24
CONSTRUCTION	FLAT PLATE	O	O						
	BONDED METAL								
	CHANNELLED CHASSIS								
	BOX AND COVER								
	BONDED STRIPLINE								
	METAL CANS								
	OTHER								
GND PLANE MAT	COPPER								
	ALUMINUM	O	O						
	KOVAR								
	STEEL								
	BRASS								
	OTHER								
# OF CIRCUITS/ SUBSTRATES	1								
	2								
	3	O							
	4								
	5								
	MORE		O						
VOLTAGE (V) (CU IN)	V ≤ 0.5								
	[illegible]	O							
	[illegible]								
	[illegible]		O						
	[illegible]								
	[illegible]								
DIELECTRIC BONDING MATERIALS	[illegible]								
	EPOXY								
	GLUE								
	GREASE								
	NONE	O	O						
	OTHER								
PACKAGE SEALING METHOD	EPOXY ENCAPSULATION								
	RUBBER GASKET								
	EDGE SOLDER								
	WELDING								
	METAL TAPE								
	GLASS SEALS								
	NONE	O	O						
	OTHER								

PACKAGING P.C. BOARD (CONT)

	SEAL MATERIALS								INTERFACE										OTHER
	CONDUCTIVE EPOXY	INSULATIVE EPOXY	CONDUCTIVE GASKET	NON-CONDUCTIVE GASKET	SOLDER	COPPER TAPE	KOVAR GLASS	OTHER	EDGE LAUNCH	BROADWALL LAUNCH	GLASS IN PIN	TNC	BNC	SMA	N TYPE	SOLDER TABS	OTHER	
17									( )		( )			( )				
18									( )		( )			( )				
19																		
20																		
21																		
22																		
23																		
24																		

APPENDIX C

BIBLIOGRAPHY

OF

TECHNICAL PUBLICATIONS

LITERATURE SEARCH INDEX

NUMBER	ARTICLE	MATERIALS	PACKAGING	COMPONENTS	MICROSTRIP	STRIPLINE	LUMPED ELEMENT	NUMBER
1.	DIELECTRIC MATERIAL DEVELOPMENT Microwave Journal Nov 78	✓			✓	✓		1
2.	BUILDING AN OSCILLATOR? Microwaves Jul 78	✓					✓	2
3.	SUPERCOMPONENTS Microwave Journal May 77	✓	✓	✓	✓	✓	✓	3
4.	SUPERCOMPONENTS Microwaves Dec 76	✓	✓	✓	✓	✓	✓	4
5.	SOLID STATE TRANSMIT/RECEIVE MODULE Microwave Journal July 78		✓		✓			5
6.	GaAs FET OSCILLATOR Microwaves July 78	✓	✓	✓	✓			6
7.	COVER PHOTO Microwaves Mar 78		✓		✓			7
8.	PRODUCT FEATURE Microwaves Jan 76		✓	✓			✓	8
9.	SUPERCOMPONENTS MSN Mar 79	✓	✓	✓	✓	✓	✓	9
10.	SUPERCOMPONENTS Microwave Journal May 77		✓	✓	✓	✓	✓	10
11.	FILTER INTEGRATION Microwave Journal May 77	✓	✓		✓	✓		11
12.	200 W. MIC Microwave Journal May 77	✓	✓	✓	✓			12
13.	THIN FILM MIXERS W-J Catalogue	✓	✓	✓		✓		13

LITERATURE SEARCH INDEX

ARTICLE		SUBJECT						
NUMBER		MATERIALS	PACKAGING	COMPONENTS	MICROSTRIP	STRIPLINE	LUMPED ELEMENT	NUMBER
14.	FUSED SILICA: A BETTER SUBSTRATE W-J Catalogue	✓			✓	✓		14
15.	INTEGRATING COMPONENTS W-J Catalogue	✓	✓	✓	✓	✓		15
16.	PHOTO-ADVERTISEMENT Western Microwave		✓		✓			16
17.	PHOTO-ADVERTISEMENT AEI		✓		✓	✓		17
18.	PHOTO-ADVERTISEMENT W-J Catalogue	✓	✓		✓	✓		18
19.	ANALOG PHASE SHIFTER Microwave Journal Mar 79	✓	✓	✓	✓	✓		19
20.	PHOTO-ADVERTISEMENT Plamic		✓		✓			20
21.	FRONT END DESIGNED FOR SHUTTLE MSN Oct 78	✓	✓	✓	✓			21
22.	ISSCC-SUMMARY Microwaves Feb 79	✓		✓	✓			22
23.	TUNNEL DIODES Microwaves Feb 79	✓		✓	✓			23
24	GET BACK TO BASICS W/ATTENUATOR Microwaves Feb 79	✓	✓	✓	✓			24
25	CATALOGUE Vectronics Microwave Corp.	✓	✓		✓			25
26	THRIFTY DOWNCONVERTER Microwaves Mar 79	✓	✓		✓	✓		26

LITERATURE SEARCH INDEX

NUMBER	ARTICLE	MATERIALS	PACKAGING	COMPONENTS	MICROSTRIP	STRIPLINE	LUMPED ELEMENT	NUMBER
27.	MOISTURE PENETRATES PACKAGE Microwaves Mar 79		✓					27
28.	PRINTED CIRCUIT INTEGRATION OF MW FILTERS Microwave Journal Sept 78	✓	✓		✓	✓		28
29.	ADVERTISEMENT Sanders		✓					29
30.	MILLIMETER-WAVE MIXERS Microwaves Sept 78	✓	✓	✓	✓	✓		30
31.	GaAs IC MSN Nov 78			✓				31
32.	BUILDING 800 + IMPATT AMPLIFIERS Microwave Journal Jan 79	✓	✓	✓	✓	✓		32
33.	CATALOGUE Diaico	✓	✓		✓		✓	33
34.	SUPERCOMPONENTS IMPROVING THROUGH COMPUTER DESIGN Microwave Systems News Mar 79	✓	✓	✓	✓			34
35.	DESIGNERS PUSH PET AMPLIFIERS 18 GHz to 26.5 GHz Microwaves May 79	✓	✓	✓	✓			35

APPENDIX D

COMPUTER ANALYSIS SUPPORTING DATA

APPENDIX D

1. Hand Calculations
2. Material Properties
3. STARDYNE and ANSYS Program Abstracts

1. Hand Calculations

Module #1 Substrate Screw Stresses

The worst-case substrate is .50 in x 1.00 in. It is secured by 4 0-80 screws. Using the 40 psi spring pressure and the 10,000g acceleration as a loading mechanism, the load per screw is,

$$F = \frac{PA + WG}{\#\text{ of Screws}} = \frac{40(.50)(1.00) + .50(1.00)(.025)(.140)(10,000)}{4}$$

$$= 9.375 \text{ LB}$$

The tensile stress is,

$$S = \frac{F}{A} = \frac{9.375}{.0018} = \underline{5,200 \text{ psi}}$$

Assuming worst-case 304 stainless steel for a screw material, the ultimate margin of safety is,

$$M = \frac{u}{S} - 1 = \frac{82,000}{5,200} - 1 = \underline{14.76}$$

Module #2 Substrate Screw Stresses

The substrate is 1.05 in x 1.25 in. Assuming the springs are compressed to .007 in, the measured spring pressure is 40 psi. There are 4 screws. Using the 10,000g acceleration and the spring pressure as a loading mechanism, the load per screw is,

$$F = \frac{PA + WG}{\# \text{ of Screws}} = \frac{40(1,95((1.25) + 1.05(1.25)(.020)(1..40)(10 \text{ psi})}{4}$$

$$= 22.31 \text{ lb}$$

The screws are 0-80, therefore the tensile stress is,

$$S = \frac{F}{A} = \frac{22.31}{.0018} = \underline{12,400 \text{ psi}}$$

Assuming worst-case 304 stainless steel as a screw material, the ultimate margin of safety is,

$$M = \frac{u}{S} - 1 = \frac{82,000}{12,400} - 1 = \underline{5.61}$$

Module #3 Cover Joint Stresses

Using the 10,000g acceleration load, the force applied to the joint is,

$$F = WG = 2.575(.75)(.015)(.100)(10,000) = 28.97 \text{ lb}$$

The tensile stress is

$$S = \frac{28.97}{.050(2(2.575) + 2(.65))} = \underline{90 \text{ psi}}$$

The ultimate margin of safety for an epoxy joint is,

$$M = \frac{u}{S} - 1 = \frac{2,000}{90} - 1 = \underline{21.22}$$

Assuming a welded joint is restored to its original temper, the ultimate margin of safety for a welded joint is,

$$M = \frac{u}{S} - 1 = \frac{75,000}{90} - 1 = \underline{832.33}$$

Module #4 Substrate Screw Stresses

The substrate is .50 in. x 1.00 in. Assume it is .025 in. thick. It is secured with 4 0-80 nylon screws. Using the 10,000g acceleration as a loading mechanism, the inertia load per screw is,

$$F = \frac{W \times G}{\text{\# of Screws}} = \frac{.50 \times 1.00 \times .025 \times .140 \times 10{,}000}{4}$$

$$= 4.375 \text{ lb}$$

The tensile stress is

$$S = \frac{F}{A} = \frac{4.375}{.0018} = \underline{2{,}430 \text{ psi}}$$

Assuming worst-case 6/9 nylon the ultimate margin of safety is,

$$M = \frac{u}{S} - 1 = \frac{5{,}000}{2{,}430} - 1 = 1.06$$

2. Material Properties

Module #1 Material Properties

Module and Cover (Aluminum, 6061-T6, Materials Selector, p. 81)

$E = 10 \times 10^6$

$\gamma = .098\ 16/in^3$

$\sigma_u = 45{,}000$ psi

Substrate (772 Alumina, 3M Alumina Handout)

$E = 55 \times 10^6$ psi

$\gamma = .140$ lb/in^3

$\sigma_u = 70{,}000$ psi (flexural)

Lead Wires (Gold, Materials Selector, p. 119)

$E = 12 \times 10^6$ psi

$\gamma = .698$ lb/in^3

$\sigma_u = 19{,}000$ psi (annealed)

Substrate Screws (Assume 304 Stainless Steel, Materials Selector, p. 44)

$\sigma_u = 82{,}000$ psi

E = Young's Modulus

γ = Weight Density

σ_u = Ultimate Strength

Module #1 RF Connector Material Properties

Female Connector (Beryllium Copper, Materials Selector, p. 92)

$E = 19 \times 10^6$

$\alpha = 9.3 \times 10^{-6}/^{\circ}F$

$\gamma = .296$ 16/in^3

Insulator (Teflon, PTFE, Materials Selector, p. 149)

$E = .65 \times 10^6$ psi

$\alpha = 8.4 \times 10^{-5}/^{\circ}F$

$\gamma = .083$ lb/in^3

$\sigma_u = 2{,}500$ psi

Case (Steel, 416 Stainless, Materials Selectro, p. 48)

$E = 29 \times 10^6$ psi

$\alpha = 5.5 \times 10^{-6}/^{\circ}F$

$\gamma = .280$ lb/in^3

$\sigma_u = 75{,}000$ psi

Male Connector (Brass, Materials Selector, p. 93)

$E = 17 \times 10^6$ psi

$\alpha = 11.3 \times 10^{-6}/^{\circ}F$

$\gamma = .318$ 16/in^3

$\sigma_u = 37{,}000$ psi

Module #1 RF Connector Material Properties (Continued)

Module (Aluminum, 6061-T6, Materials Selector, p. 81)

$E = 10 \times 10^6$ psi

$\alpha = 13 \times 10^{-6}/^{\circ}F$

$\gamma = .098$ lb/in^3

$\sigma_u = 45{,}000$ psi

Kovar Shell (Kovar, Kovar Handbook)

$E = 20 \times 10^6$ psi

$\alpha = 3.05 \times 10^{-6}/^{\circ}F$

$\gamma = .302$ lb/in^3

$\sigma_u = 75{,}000$ psi

Glass (7052 Glass, Ed Sharp, Corning Glass Works, Corning N.Y. 607-974-7634)

$E = 8.2 \times 10^6$ psi

$\alpha = 25.6 \times 10^{-7}/^{\circ}F$

$\gamma = .082$ lb/in^3

$\sigma_u = 7{,}000 - 14{,}000$ psi

E = Young's Modulus

α = Coefficient of Expansion

γ = Weight Density

σ_u = Ultimate Strength

Module #1 DC Feedthru Material Properties

Wire (Alloy 52, Kovar Handbook)

E = 20×10^6 psi (assume same as Kovar)

α = $5.61 \times 10^{-6}/^{\circ}F$

γ = .300 lb/in^3

μ = .317 (assume value for Kovar)

σ_u = 65,000 psi

Case (C1213-1215 Steel, Assume C1015 Steel, Materials Selector, p. 34)

E = 30×10^6 psi

α = $8.40 \times 10^{-6}/^{\circ}F$

γ = .283 lb/in^3

u = .30 (assumed)

σ_u = 73,000 psi

Hermetic Seal (9010 Sealing Glass, Ed Sharp, Owens-Corning, Corning, N.Y. 607-974-7634

E = 9.8×10^6 psi

α = $49.4 \times 10^{-7}/^{\circ}F$

γ = .095 lb/in^3

u = .22 (Materials Selector, p. 215)

σ_u = 7,000 - 14,000 psi

Module #1 DC Feedthru Material Properties (Continued)

Epoxy Seal (Emerson-Cummings 2651-MM Epoxy, Emerson-Cummings Handbook

$E = .70 \times 10^6$ psi

$\alpha = 22 \times 10^{-6}/°F$

$\gamma = .056$ lb/in^3

$u = .30$ (assumed)

$\sigma_u = 7{,}000$ psi (tensile)

Ceramic (Barium Titanate, Joe Long, Int'l Tin Research Institute, Columbus, Ohio 614-424-6200)

$E = 16 \times 10^6$ psi

$\alpha = 6.75 \times 10^{-6}/°F$

$\gamma = .131$ lb/in^3 (assumed)

$u = .30$ (assumed)

$\sigma_u = 11{,}700$ psi

Solder (62% Tin, 36% Lead, 2% Silver, Joe Long, above)

$E = 6.37 \times 10^6$ psi

$\alpha = 14.3 \times 10^{-6}/°F$

$\gamma = .318$ lb/in^3

$u = .40$ (assumed)

$\sigma_u = 6{,}120$ psi

Module #1 DC Feedthru Material Properties (Continued)

Module (Aluminum, 6061-T6, Materials Selector, p. 81)

$E = 10 \times 10^6$

$\alpha = 13.0 \times 10^{-6}/^{\circ}F$

$\gamma = .098\ lb/in^3$

$u = .30$ (assumed)

$\sigma_u = 45{,}000$ psi

Module #2 Material Properties

Substrate Screws (Assume 304 Stainless Steel, Materials Selector, p. 44)

σ = 82,000 psi

Substrate (Fused Silica, Materials Selector, p. 215)

E = 10.5×10^6 psi

γ = .079 lb/in^3

u = .16

σu = 7,000 psi (assumed same as glass)

E = Young's Modulus

γ = Weight Density

u = Poisson's Ratio

σu = Ultimate Strength

Module #3 Material Properties

Epoxy (Abelbond 36-2, Herb Krause, Ablestik Lab, Gardenia, CA 213-532-9341)

E = 518,000 psi

α = $58.3 \times 10^{-6}/^{\circ}F$

γ = .087 lb/in^3

σ_u = 2,000 psi (tensile)

Module and Cover (Kovar, Kovar Handbook)

E = 20×10^6 psi

α = $3.05 \times 10^{-6}/^{\circ}F$

γ = .302 lb/in^3

σ_u = 75,000 psi

E = Young's Modulus

α = Coefficient of Expansion

γ = Weight Density

σ_u = Ultimate Strength

Module #4 Material Properties

Substrate Screws (Assume 619 Nylon, Materials Selector, p. 151)

$\sigma_u = 5{,}000$ psi

Substrate (772 Alumina, 3M Alumina Handout)

$\sigma_f = 70{,}000$ psi

σ_u = Ultimate Strength

σ_f = Flexural Strength

AD-A090 677 HARRIS CORP MELBOURNE FL GOVERNMENT INFORMATION SYST--ETC F/G 9/5
MICROWAVE INTEGRATED CIRCUITS PROCEDURES EVALUATION.(U)
JUN 80 M F BELGIN, B C MITCHELL, V R BEAHY F30602-78-C-0335

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Module #5 Material Properties

Module (Aluminum, 6061, T-6, Materials Selector, p. 81)

$E = 10 \times 10^6$ psi

$\alpha = 13 \times 10^{-6}/^{\circ}F$

$\gamma = .098$ lb/in^3

$\sigma_u = 45{,}000$ psi

Solder (62% Tin, Joe Long, Int'l Tin Research Institute, Columbus, Ohio 614-424-6200)

$E = 6.37 \times 10^6$ psi

$\alpha = 14.3 \times 10^{-6}/^{\circ}F$

$\gamma = .318$ lb/in^3

$\sigma_u = 6{,}120$ psi

Lead (Gold, Materials Selector, p. 119)

$E = 12 \times 10^6$ psi

$\gamma = .698$ lb/in^3

$\sigma_u = 19{,}000$ psi

Module #5 Material Properties (Continued)

Substrate

G-2 (Materials Selector, p. 266)

$E = 1.8 \times 10^6$

$\alpha = 9 \times 10^{-6}/^\circ F$ (in plane of plate) $= 81 \times 10^{-6}/^\circ F$ (assumed same proportion as G-10 for thickness direction)

$\gamma = .054\ lb/in^3$

$\sigma_u = 11{,}000$ psi

G-10 (Materials Selector, p. 266)

$E = 2.5 \times 10^6$ psi

$\alpha = 5 \times 10^{-6}/^\circ F$ (in plane of plate) $= 45 \times 10^{-6}/^\circ F$ (in thickness direction

$\gamma = .065\ lb/in^3$

$\sigma_u = 35{,}000$ psi

Teflon (3M Handout)

$E = .70 \times 10^6$ psi

$\alpha = 5.55 \times 10^{-6}/^\circ F$ (in plane of plate) $= 72.2 \times 10^{-}/^\circ F$ (in thickness direction)

$\gamma = .079\ lb/in^3$

$\sigma_u = 20{,}500$ psi

Module #6 Material Properties

Module (Aluminum, 6061-T6, Materials Selector, p. 81)

$E = 10 \times 10^6$ psi

$\alpha = 13 \times 10^{-6}/°F$

$\gamma = .098$ lb/in^3

$\sigma_u = 45{,}000$ psi

Substrate (K-6098 Teflon, 3M Handout)

$E = .70 \times 10^6$ psi

$\alpha = 5.55 \times 10^{-6}/°F$ (in plane of plate) $= 72.2 \times 10^{-6}/°F$ (in thickness direction

$\gamma = .079$ lb/in^3

$\sigma_u = 20{,}500$ psi

Epoxy (Ablebond 36-2, Herb Krause, Ablestik Lab, Gardenia, CA 213-532-9341)

$E = .518 \times 10^6$ psi

$\alpha = 58.3 \times 10^{-6}/°F$

$\gamma = .087$ lb/in^3

$\sigma_u = 2{,}000$ psi

E = Young's Modulus

α = Coefficient of Expansion

γ = Weight Density

σ_u = Ultimate Strength

3. STARDYNE and ANSYS Program Summaries

The reproduction of the STARDYNE Analysis System was approved by the System Development Corporation, 2500 Colorado Avenue, Santa Monica, CA. 90406.

Reproduction of the abstract of the ANSYS User's Manual was approved by Swanson Analysis Systems Inc., Johnson Road, P.O. Box 65, Houston, PA. 15342.

STARDYNE ANALYSIS SYSTEM

SUMMARY

The MRI STARDYNE Analysis System consists of a series of compatible digital computer programs designed to analyze linear elastic structural models. The system encompasses the full range of static and dynamic analyses. These programs provide the analyst with a sophisticated, cost-effective, structural-dynamical analysis system.

The STARDYNE system can be used to evaluate a wide variety of static and dynamic problems:

- The static capability includes the computation of structural deformations and member loads and stresses caused by an arbitrary set of thermal, nodal applied loads and/or prescribed displacements.
- Utilizing either the direct integration or the normal mode techniques, dynamic response analyses can be performed for a wide range of loading conditions, including transient, steady-state harmonic, random and shock spectra excitation types. Dynamic response results can be presented as structural deformations (displacements, velocities, or accelerations), and/or internal member loads/stresses.

The data input and output formats (both numerical and graphical) have been prepared with one basic philosophy: to enable the user to obtain a meaningful solution in the most logical and straightforward manner possible while keeping the required data input as simple and minimal as practical. The programmed mathematical operations in the matrix

decomposition, the eigenvalue-eigenvector extraction, and the error analysis, contain state-of-the-art innovations in the field of numerical analysis. A brief description of the finite element and normal mode analysis methods as they are implemented in STARDYNE is presented. Also included is a discussion on each of the major programs comprising the STARDYNE system.

THE FINITE ELEMENT, NORMAL MODE ANALYSIS METHOD

The basic concept of the "Finite Element" method is that every structure may be considered as a "mathematical" assemblage of individual structural components or elements. There must be a finite number of such elements, interconnected at a finite number of nodal points. The behavior of this finite element structural model will closely approximate the behavioral characteristics of the real structure.

Components of the Structural Model. The physical structure to be modeled must be described in a right-hand cartesian coordinate (global) system and is comprised of the "nodes" and "finite elements".

Nodes. The characteristics of the node point include position in space, movement in space (3 translation x, y, z and 3 rotation θ_x, θ_y, θ_z) and connectivity to other nodes via the finite elements. Masses and external forces may be assigned to each node.

Finite Elements. The node points may be interconnected with finite elements in such a way as to realistically represent real physical structures. The most commonly used elements are shown on page A - 53, together with the nodal forces which can be transmitted through the element. The stiffness properties of each of these finite elements are defined in the "STARDYNE Theoretical Manual".

General Solution Procedure. The general solution procedure consists of stiffness matrix formulation, static analysis, eigenvalue/eigenvector determination, and dynamic response analysis.

Stiffness Matrix Formulation. The stiffness matrices of the individual finite elements are first computed and then transformed (if required) from its local coordinate formulation to a form relating to the global coordinate system. Finally, the individual element stiffnesses contributing to each nodal point are superimposed to obtain the total assemblage stiffness matrix [K].

Static Analysis. During a static analysis, the equation

$$[K] \cdot \{\ \} = \{P\}$$

where $[K]$ = the stiffness matrix

$\{\ \}$ = the nodal displacement vector

$\{P\}$ = the applied nodal forces

may be solved to determine the nodal displacements and element internal forces and/or stresses given a set of applied nodal forces.

Eigenvalue/Eigenvector Analysis. The eigenvalues (natural frequencies) and eigenvectors (normal modes) of a structural system are determined by solving the equation.

$$w^2 \ [m]\{q\} - [K]\{q\} = 0$$

where [m] = the mass matrix (assumed to be diagonal, i.e., no mass coupling)

ω = the natural frequencies

{q} = the normal modes.

Dynamic Response Analyses. Using the natural frequencies and normal modes together with the related mass and stiffness characteristics of the structure, appropriate equations of motion may be evaluated to determine structure response to dynamic loading.

PROGRAMS COMPRISING STARDYNE ANALYSIS SYSTEM

1. STAR (Project Engineer: Raymond Curtis)

   The STAR program has two distinct functions. They are static load analysis and eigenvalue/eigenvector extraction. The static analysis and modal extraction phases are based on the "Stiffness Method" or "Displacement Method" and the answers are in the realm of "Small Displacement Theory".

   A. Available Finite Modeling Elements

      1. Beam and Pipe elements with shear stiffness in 3-D space.
      2. Two Triangular Plate Elements (Thick plate and thin plate)
         a. Plate Bending
         b. Sandwich (Thick plate only)
         c. Inplane (constant strain)
         d. Shear Only (Thick plate only)
      3. Quadrilateral Plate Element (Iso-parametric in-plane)

4. Infinitely Rigid Members
5. Springs, non-standard elements or substructures may be entered in numerical form, by direct alterations to the stiffness matrix.
6. Hexahedron (Cube) Solid Element (Iso-parametric)
7. Wedge Solid Element (Iso-parametric)
8. Tetrahedron Solid Element (constant strain)

B. <u>Static Structural Analysis</u>

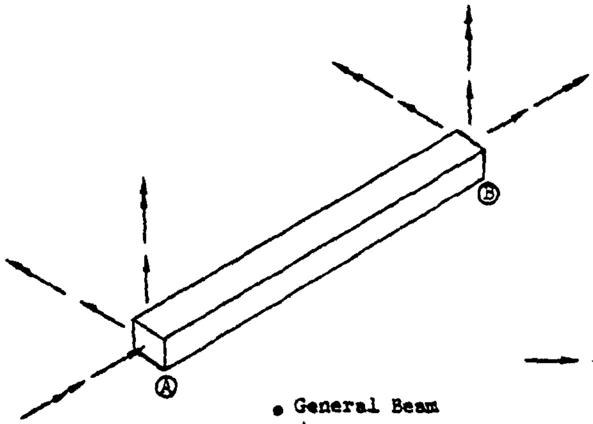
1. Applied Nodal Loadings
2. Automated Thermal Analysis
3. Solutions of Free-Free Systems
4. Automated processing of psuedo-static load or displacement vectors as obtained from the dynamic response solutions
5. Element Loadings
6. Inertia Loadings
7. Combined Cases
8. Specified Displacements
9. Substructures

C. <u>Extraction of Eigenvalues and Eigenvectors</u>

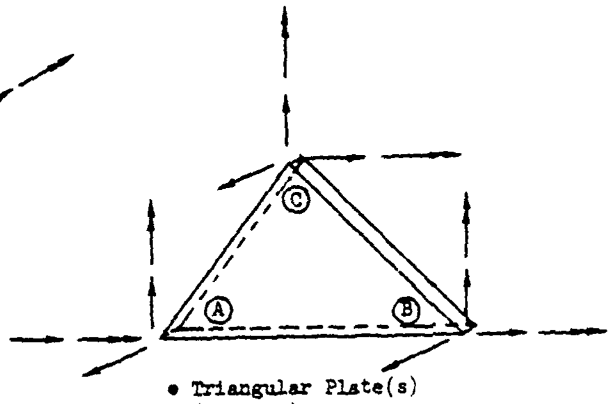
1. Inverse Iterations Method for the eigenvalues within specified regions (uses full system weight vector)

STARDYNE ANALYSIS SYSTEM - SUMMARY - CONTINUED

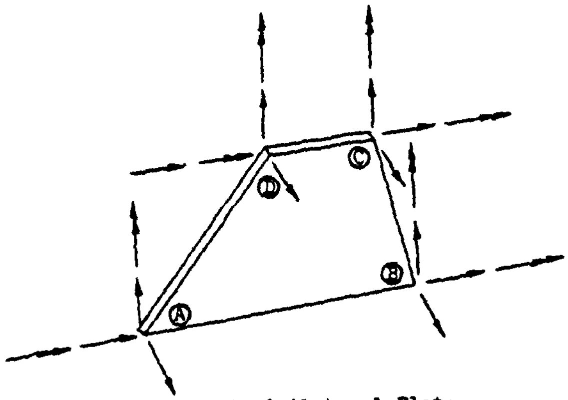
- Commonly Used Finite Elements



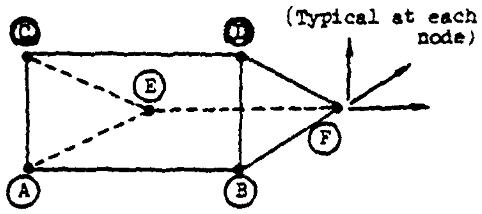
- General Beam
  (2 nodes)



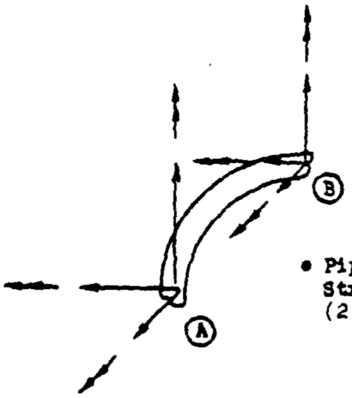
- Triangular Plate(s)
  (3 nodes)



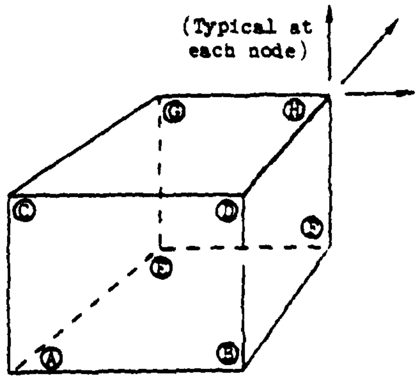
- Quadrilateral Plate
  (4 nodes)



- Wedge Element
  (6 nodes)



- Pipes-Curved and Straight
  (2 nodes)



- General Six Sided Solid (Hexahedron)
  (8 nodes)

2. Householder tri-diagonalization and Q-R extraction for reduced dynamic degrees of freedom - GUYAN reduction (usually used for truncated weight vector).

3. LANCZOS Modal Extraction Method (uses full system weight vector, no nodal limitations - this is a highly recommended method).

D. Output Section

STAR output processor phase computes element displacements, loads and stress; and nodal equilibrium check. Options are available to present the output in report form.

2. DYNRE1 (Project Engineer: Richard Ragle)

Transient response to imposed dynamic loadings are treated in DYNER1 using the modal superposition technique. Input forcing functions may be in the form of forces, initial displacements, initial velocities and base accelerations. Output consists of nodal displacements, velocities, accelerations, element loads and stresses.

3. DYNRE2 (Project Engineer: Richard Ragle)

Steady state frequency response to steady state sinusoidal dynamic loadings are computed by DYNRE2. Input forcing functions may be in the form of distributed forces, base excitations (displacements, velocities or accelerations) and unit sinusoidal excitations (displacements, velocities, accelerations or forces) as specific nodes. Displacements at selected phase angles may be processed in STAR for element stresses.

4. DYNRE3 (Project Engineer: Richard Ragle)

   Response of multi-degree-of-freedom linear elastic structural models subjected to stationary random dynamic loading. DYRNE3 will compute the RMS nodal responses, RMS element stresses and generate response power spectral density (PSD) curves for selected nodal degrees of freedom. Input forcing power spectrums are defined as shape of spectrum and type of spatial correlation.

5. DYNRE4 (Project Engineer: Richard Ragle)

   Response of multi-degree-of-freedom, linear elastic models subjected to an arbitrarily oriented foundation shock input. The user may enter arbitrary shock spectra, shock spectra computed via DYRNE5, or call for some ratio of the 1940 El Centro (California) earthquake SPECTRA for any of the directions of motion. DYNRE4 will compute user specified combinations of ABSOLUTE and/or RSS and/or NRL sum and various NRC sum-summation for nodal and/or element stress responses.

6. DYNRE5 (Project Engineer: Richard Ragle)

   Computes shock spectrum values from a transient base acceleration time history digitized at equal or unequal time intervals. The user may specify frequencies at which shock spectrum values for displacement, velocity and acceleration will be computed, in turn for each value of damping entered.

7. DYNRE6 (Project Engineer: Raymond Curtis)

   Computes the response of multi-degree-of-freedom structures subjected to transient dynamic loadings, using the direct integration technique. The model may also contain nonlinear one-dimensional springs.

8. PLØT3D (Project Engineer: Richard Ragle)

   This program may be used to plot STAR finite element structural models. It enables the user to view the geometric structure in both the undeformed and deformed states. The deformations may be the result of a STATIC, Modal Extraction or a Dynamic Response solution.

9. CØNSTAR (Project Engineer: Raymond Curtis)

   This program may be used to produce contour plots of stresses and displacements on surfaces composed of triangular and quadrilateral elements. In addition, the numerical response values may be printed directly on the plot.

10. WAVE4 (Project Engineer: Charles Bell)

    This program may be used to compute hydrodynamic forces on the tubular and/or circular beam members contained in the submerged portion of a STAR model. The fluid forces can result from both wave motion and a steady current. The wave motion is defined by Stoke's 5th Order Theory.

11. SPRING (Project Engineer: Charles Bell)

    This program may be used to determine the loads and deformations in a linear elastic structure supported by a nonlinear foundation, and subjected to general static loading.

12. NUBØP (Project Engineer: Richard Ragle)

    This program may be used to consider bottom out, tension only, compression only members, etc., for the STAR STATICS problem.

13. NØDEXC

    This program may be used to change node numbers of STAR substructure boundary data to match the boundary node numbers of the recipient math model. NØDEXC may be used on either the FORWARD or BACKWARD SUBSTRUCTURE PASS.

14. PØST (Project Engineer: Charles Bell)

    This program may be used to combine the forces, stresses, and displacements from two (or more) previously computed load cases which are contained in the STAR TAPE4 format.

15. FACTØR

    This program may be used to create new force and/or displacement vectors using combinations of these vectors entered in the STAR TAPE4 and/or DYNRE TAPE3 data file formats.

16. USER INFORMATION MANUAL (Originator/Editor: Richard Ragle)

ABSTRACT

The ANSYS computer program is a large-scale general purpose computer program for the solution of several classes of engineering analysis problems. Analysis capabilities include static and dynamic; elastic, plastic, creep and swelling; small and large deflections; steady state and transient heat transfer and fluid flow.

The matrix displacement method of analysis based upon finite element idealization is employed throughout the program. The library of finite elements available numbers more than forty for static and dynamic analyses, and twenty for heat transfer analyses. This variety of elements gives the ANSYS program the capability of analyzing two- and three-dimensional frame structures, piping systems, two-dimensional plane and axisymmetric solids, three-dimensional solids, flat plates, axisymmetric and three-dimensional shells and nonlinear problems including interfaces and cables.

Loading on the structure may be forces, displacements, pressures, temperatures or response spectra. Loadings may be arbitrary time functions for linear and non-linear dynamic analyses. Loadings for heat transfer analyses include internal heat generation, convection and radiation boundaries, and specified temperatures or heat flows.

The ANSYS program uses the wave front (or "frontal") direct solution method for the system of simultaneous linear equations developed by the matrix displacement method, and gives results of high accuracy in a

minimum of computer time. The program has the capability of solving large structures. There is no limit on the number of elements used in a problem. There is no "band width" limitation in the problem definition; however, there is a "wave front" restriction. The "wave front" restriction depends on the amount of core storage available for a given problem. Up to 577* degrees of freedom on the wave front can be handled in a large core. The wave front limitation tends to be restrictive only for analysis of arbitrary three-dimensional structures or in the use of ANSYS on a small computer.

ANSYS has the capability of generating substructures (or superelements). These substructures may be stored in a library file for use in other analyses. Substructuring portions of a model can result in considerable computer time savings for non-linear analyses.

Geometry plotting is available for all elements in the ANSYS library, including isometric, perspective, section views, and hidden line plots of three-dimensional structures. Plotting routines are also available for the plotting of stresses and displacements from two- and three-dimensional solid or shell analyses, mode shapes from dynamic analyses, distorted geometries from static analyses, transient forces and displacements vs. time curves from transient dynamic analyses, and stress-strain plots from plastic and creep analyses.

Postprocessing routines are available for algebraic modification, differentiation, and integration of calculated results. Root-sum-square

*An optional 1152 wave front is available on very large computers.

operations may be performed on seismic modal results. Response spectra may be generated from dynamic analysis results. Results from various loading modes may be combined for harmonically loaded axisymmetric structures.

The input data for the ANSYS program has been designed to make it as easy as possible to define the problem to the computer. Options for multiple coordinate systems in cartesian, cylindrical, or spherical coordinates are available, as well as multiple region generation capabilities to minimize the input data for repeating regions.

Sophisticated geometry generation capabilities are included for two-dimensional plane and axisymmetric structures and for intersection three-dimensional shell and solid structures.

The ANSYS program capabilities are continually being enhanced by the addition of new or improved elements, new analysis capabilities, and new input, output and graphic techniques. The ANSYS USER'S MANUAL is modified periodically to reflect the latest additions.

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